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THE PILTDOWN FRAUD: AVAILABLE EVIDENCE REVIEWED¹

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THE CHEMICAL EVIDENCE (K.P.O.)

A number of anthropologists from Waterston, Miller and Boule onwards have stated categorically that the Piltdown mandible is that of an ape; but they all assumed that it was of Pliocene or Lower Pleistocene age. In September, 1948, following the successful application of the "fluorine test" to the Galley Hill skeleton and Swanscombe skull, it was decided to drill small samples from the Piltdown mandible, canine and cranial fragments, and to compare their fluorine content with that of the fossils of various ages recorded from the site. The analyses were carried out by Dr. C. R. Hoskins in the Department of the Government Chemist, London, and the results indicated beyond doubt that the cranial bones, mandible and canine were all considerably younger than Lower Pleistocene. They were estimated to contain on an average 0.2% F, compared with 2.0% F in Lower Pleistocene specimens. No appreciable difference between the fluorine content of the cranium and of the mandible or teeth was noted, but the experimental error on samples of the very small size tested was large enough to obscure such a difference if it were less than 0.1%. Assuming that all these specimens were fossils it was concluded that the cranial bones, the mandible and

¹Based on the preliminary report in the *Bulletin of the British Museum* (Natural History), Geological series, Vol. 2, No. 3, "The Solution of the Piltdown Problem," by J. S. Weiner, K. P. Oakley and W. E. Le Gros Clark, 1953, and on a Discussion at the Geological Society of London, November 25, 1953.

²We are deeply grateful to Prof. W. E. Le Gros Clark for allowing us to quote from his anatomical observations on the Piltdown dentition.

the canine tooth were all of the same relatively late age, probably Upper Pleistocene.

From an anatomical point of view this made it even more difficult to accept the mandible and canine as belonging to the same individual as the brain-case. The existence of an ape in Britain in Upper Pleistocene times was equally difficult to conceive. The Piltdown puzzle seemed insoluble until Weiner suggested in July, 1953, that the mandible and canine might be those of a modern ape treated so as to simulate fossils. The fluorine content of the mandible as recorded in 1949 (0.2%) had not appeared to allow that solution, but as it was based on analysis of only a few milligrams of material, re-determination of the fluorine content was required to test this hypothesis. New samples of the critical specimens were submitted to the Department of the Government Chemist, where they were analyzed by Mr. C. F. M. Fryd, using an improved technique making it possible to estimate small amounts of fluorine more accurately. The results showed that, whereas the Piltdown cranium might be Upper Pleistocene, as claimed in 1949, the mandible and canine tooth were modern.

	% F
Minimum in local Upper Pleistocene bones and teeth	0.1
Piltdown cranial bones	0.1
Piltdown mandible	< 0.03
Piltdown molar	< 0.04
Piltdown canine	< 0.03
Recent molar	< 0.06

When the mandible was being drilled deeply with a dental burr to procure an adequate sample for the re-determination of fluorine, there was an odor of burning, and the ejection consisted of minute shavings. When the cranial bones were drilled in the same way there was no odor, and the sample consisted of powder.

Chemical studies of bones from early occupation sites in North America by Cook and Heizer have shown that, in bones buried under the same conditions, the nitrogen content is a rough guide to antiquity. Mrs. A. Foster (who, with Dr. J. D. H. Wiseman, in the Department of Minerals of the British

Museum, recently perfected a method of determining the nitrogen content of microgram samples) undertook the estimation of nitrogen in samples of the critical Piltdown specimens and selected controls. The results confirmed the evidence obtained from fluorine analysis.

	% N
Fresh bones and teeth	c. 4.0
Piltdown mandible	3.9
Piltdown molar	4.3
Piltdown canine	5.1
Piltdown cranial bones	c. 1.4
Local Upper Pleistocene bones and teeth (provisional estimate)	< 1.5

The dentine of the canine proved to be pure white below a blackish film of some flexible paint-like substance, the precise nature of which is still being investigated.

Woodward ('48) stated that the pieces of skull which were first discovered had been dipped by Dawson in a solution of potassium dichromate, with the mistaken idea that this would harden them. The cranial fragments found while Woodward was digging with Dawson at Piltdown have *not* been chromate stained. The mandible on the other hand, although found in Woodward's presence, *is* chromate stained, indicating that it was treated prior to its reported extraction from the gravel, i.e., it had been "planted." (The chromate staining of the specimens was tested by Drs. M. H. Hey and A. A. Moss in the Department of Minerals at the British Museum, and by Mr. E. T. Hall in the Clarendon Laboratory, Oxford.)

It is possible that the specimens were steeped first in gelatine and then in a dichromate solution, for this is a rational means of hardening soft specimens. However, if this gelatine were the source of the greater part of the nitrogen detected in the specimens, the cranial bones which are porous should contain *more* nitrogen than the compact dentine of the teeth, whereas the reverse is true.

Analyses have also been made of the frontal and occipital fragments which were recorded as being found at a second site together with an isolated molar tooth which Hrdlička

('30) regarded as almost certainly from the Piltdown mandible of the first site. The frontal fragment of "Piltdown II" could, anatomically, form part of the cranium of Piltdown I, with which it agrees in its fluorine and nitrogen content. The occipital fragment, on the other hand, does represent another individual, but it contains no more fluorine than some recent bones (0.03%). Its nitrogen content is low (0.6%), but in a bone which may have been exposed on the surface for some time this is no proof of antiquity (whereas high nitrogen content in a bone from an oxidized deposit is a clear indication of relative modernity). It has been suggested that this piece was artificially stained with chromate and iron in an attempt to match the color of the more mineralized frontal fragment.³

EVIDENCE OF THE WEAR OF THE TEETH (J.S.W.)

The composition of the mandible and of the canine leaves no doubt that they are modern. The evidence of the staining and also of artificial abrasion shows that they were not only modern but fraudulent.

Before discussing this evidence further, it may be of interest to recount how anatomical considerations led to the strong supposition that the Piltdown remains were in part a fake.

That the mandible is overwhelmingly ape-like is a fact which was, of course, stressed by Smith Woodward from the beginning, and has been demonstrated in detail by many others, of whom in particular should be mentioned Waterston ('13) and Miller ('15). Marston ('52) has insisted on the similarity of the canine to that of an upper canine of a modern orang. When reconsidering the Piltdown problem in July this year, the point which emerged particularly was that there appeared to be only a single feature of the jaw and dentition which could not be said to be definitely ape-like, namely, the wear of the molars and canine. It seemed surprising, on anatomi-

³ Further chemical evidence bearing on this question will be presented in the second paper on the Piltdown Problem, to be published in a forthcoming part of the *Bulletin of the British Museum (Natural History)*.

cal as well as evolutionary grounds, that this should be the only undoubted feature to link the cranium and the mandible. This feature alone prevented the jaw from being ascribed to a modern ape, for the 1949 fluorine analysis (Oakley and Hoskins, '50) had not only removed it from the Lower Pleistocene dating, but had left its antiquity rather indeterminate, and even allowed one to suppose that one was not necessarily dealing with a fossil. Moreover, in the same paper, Oakley recorded that the canine under the thin "feruginous" layer was astonishingly white and fresh. The question became simply — how could such peculiar wear have been produced in a mandible, possibly quite modern, and which doubtless possessed an ape's glenoid articulation? The possibility that the teeth had been artificially worn down obtained strong initial support from the fact that the nature of the wear of the canine has always been so baffling.

The evidence of artificial abrasion is as follows:

Molar teeth of the mandible.

1. The occlusal surfaces (particularly of M_2) are planed down over almost their whole extent to a flatness which is much more even than that normally produced by natural wear.

2. The borders of the flat occlusal surfaces — particularly the lateral borders — are sharp-cut and show no evidence of the bevelling which is usually produced by natural wear.

3. The center of the talonid basin in M_2 is unworn, and is bounded by a sharp-cut and unbevelled border of the planed surface of the crown. This appearance would be produced by artificial abrasion, but would not be expected in natural wear.

4. The surface of the areas of dentine exposed on the antero-medial cusps of the two molars is quite flat and flush with the surrounding enamel, instead of forming a depression as would be expected in natural wear.

5. In both molars much more dentine has been exposed on the antero-internal than the antero-external cusps. But, in the course of natural attrition, the lateral cusps of lower molar teeth are normally worn down more rapidly (and thus

usually show a great exposure of dentine) than the medial cusps.

6. The degree of wear in the two molars, M_1 and M_2 , is almost identical. But in early stages of natural attrition M_1 is commonly (though not always) more severely worn than M_2 .

7. The planes of the flat occlusal surfaces of the two molars are not congruous, i.e., they do not fit together to form a uniform contour.

8. Inspection of the isolated molar tooth ("Pittdown II") with a binocular microscope shows that the occlusal surface of the enamel has been finely scratched as though by an abrasive.

Canine tooth.

1. The mode of wear of this tooth is unlike that found normally in ape or human canines, for the abraded surface has exposed the dentine over the entire lingual surface from medial to distal border, and at one point actually reaches the apex of the pulp cavity.

2. The condition of the apex of the root, and the wide and open pulp cavity seen in an x-ray photograph, indicate fairly certainly that the canine was still incompletely erupted or had only just recently completed its eruption. But this would be incompatible with the severe attrition of the crown if the latter were naturally produced.

3. X-ray examination shows no evidence of the deposition of secondary dentine (with a constriction of the pulp cavity) which might be expected if the severe abrasion of the lingual surface of the crown were the result of natural attrition.

4. The abraded surface of the crown shows fine vertically disposed scratches (as seen under a binocular microscope) which suggests the application of an abrasive.

In the discussion at the Geological Society (Nov. 25, 1953), Marston ignored the chemical evidence as well as the other facts presented by Oakley. He did not produce any data in support of his claim that the mandible is that of a fossil ape, other than a reference to slight and quite equivocal fea-

tures in the morphology of the jaw and the canine. Indeed, he has taken considerable pains in his recent papers to emphasize the close anatomical similarities which the jaw and teeth bear to modern simian, and particularly orang, specimens. On the other hand, he has merely offered a quite hypothetical explanation for the production of the dental wear in this postulated fossil ape. The presence of sand grains in the canine was the only point which Marston brought forward as evidence of fossilization of this tooth, quite ignoring its high nitrogen content, its low fluorine content, the fact that the so-called ferruginous layer is flexible, that the heavy wear is in complete contradiction to the size of the pulp cavity, and the absence of secondary dentine. The sand grains are, in fact, not consolidated, and are quite loose; they could thus have been inserted deliberately.

In summary, then, we have in the Piltdown mandible and teeth specimens which are quite recent. The features of the wear are not to be found in those of modern apes, and have been produced, as they could only have been produced, by deliberate interference.

Lastly, it should be recorded that the identity of the hoaxer still remains unknown.

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BIOMETRY AND MENDELISM.—Of the many adjectives which one hears and sees applied to the word “genetics” some are meaningful, while many others imply some distinction scarcely worth making. The wide applicability of Mendel’s principles invites a classification based on the subject-matter, such as human genetics, *Drosophila* genetics, mouse genetics, plant genetics, and so on, but no distinction of importance can be made in this way. . . .

The first major distinction that I should make is between the genetics of quantitative characters, dependent on the cumulative action of numerous factors, and the genetics of distinct and recognizable *loci* in the germplasm. These differ in the technical equipment required of the geneticist, and in their fields of application. In the evolution of species by natural selection, certainly, it is the quantitative characters that are of principal importance; this is equally true in the selective improvement of domesticated animals, and cultivated plants; or, again, in any serious effort to control the mental and physical deterioration of the human race. The means of study are of course through experimental breeding, but *faute de mieux* what can be observed are biometrical quantities, means, variances and covariances, and third degree statistics, rather than the frequencies of manifestations of individual items characteristic of Mendelian work proper, and by means of which alone we can hope to build up cumulative knowledge of the structure and content of the germplasm, and of the fundamental laws of its behavior. In making this distinction the last thing I should wish to imply is that the study of singly recognizable gene substitutions should be neglected at centers for animal and plant improvement; on the contrary, far too little attention has been given to this aspect of genetic knowledge in our larger farm animals. . . . By contrast, the study of human genetics has been completely revolutionized in recent years by the genetical study, not of quantitative characters, but of the blood groups, yet it is not in respect of blood groups that human deterioration is to be feared. The fact is that we must rid ourselves of the last traces of that antagonism which so sorely impeded the progress both of biometry and of Mendelism 50 years ago, and recognize that both types of technical training are needed if serious progress is to be made in any real genetical problem, and that university education should be reformed so as to allow both types of study to be pursued by the same students, without allowing or, still less, inculcating, the presumption that proficiency in either one is any substitute for proficiency in the other.—SIR RONALD FISHER. Population genetics. Proc. Roy. Soc., Ser. B: Biol. Sci., vol. 141, no. 905, 9 Sept., 1953, pp. 510–523.

DATING OF THE AUSTRALOPITHECINAE OF AFRICA

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SIX FIGURES

Morphologically the Australopithecinae are in some respects so well fitted to be ancestral to the known tool-making genera of Hominidae (*Pithecanthropus* and *Homo*) that their dating relative to the earliest representatives of these has become a matter of considerable importance. Published estimates of the geological age of the australopithecine deposits have varied from Upper Pleistocene (Broom, '37) to Upper Pliocene — or, in the case of the deposit at Taung, “possibly even Middle Pliocene” (Broom and Schepers, '46). As the terms Pleistocene and Pliocene are not always applied in the same way by different workers, it seems better for the time being to avoid them in connection with this particular problem, and to use instead African stage names which are less ambiguous.

An attempt has been made by the author, on the basis of a recent research tour, to decide two questions in connection with the antiquity of the South African australopithecines: (1) whether all the known species belong to a single stage and were living simultaneously, as suggested by Professor L. C. King's reading of the geological evidence ('51), or if they have different ranges in time as J. T. Robinson has inferred ('52); (2) whether any or all of them antedate the oldest evidence of tool-making Hominidae in South Africa, as has been widely claimed.

Combining all lines of evidence it is concluded that the known species of *Australopithecus*¹ range from the middle

¹ The use of a single generic name to cover all the known australopithecines has been proposed by Washburn and Patterson ('51). But compare Broom ('50).

of the Kageran (= Upper Villafranchian) into the Lower Kamasian stage; that none is certainly older than the earliest recognized pebble-tools (found for instance in early Kageran gravels in Uganda), and that some were undoubtedly contemporary with tool-makers in South Africa. The possibility that the pebble-tools were made by *Australopithecus* has therefore to be borne in mind, but there is no evidence pointing strongly in that direction, and on general grounds it appears most improbable.

The following is a brief review of the dating evidence. It is of several kinds, not all of equal value, and will be considered site by site.

Makapan

There are many caves and fissures in the dolomite which forms the sides of the now almost dry Makapansgat valley, northeast of Potgietersrust in Central Transvaal (Barbour, '49; King, '51). They contain layers of dripstone (travertine), cave-earth and breccia. In all these caves, lime-workers have extracted the layers of dripstone (pure calcium carbonate), leaving *in situ*, or breaking up and discarding on dumps, the indurated cave-earths and breccias. Workings at the Lime-works Cave (pl. 1, below left), 150–200 feet above the floor of the valley, have revealed a sequence of bone-bearing deposits in which Professor Raymond Dart and his associates recognize a lower grey zone (10 ft.), a middle pink zone (1–20 ft.) and an upper red zone (up to 20 ft.). Remains of 5 or 6 individuals of *Australopithecus prometheus* Dart have been found in loose blocks of the lower grey zone. (See Dart, '48, ff.) The fauna at this level is of savannah type and the presence of *Hippopotamus* indicates the proximity of permanent water. About one-third of the 35 or more species in this fauna belong to extinct genera,² which agrees well with its reference to the Kageran pluvial (Dart, '52, 101). However, several of the extinct genera persist into the Kamasian and even

² I am indebted to Dr. L. H. Wells for this provisional assessment.

into the Gamblian, while a fair number of the species are not distinguishable from Gamblian or Recent forms; so the possibility that the Makapan fauna is *pre*-Kageran can be discounted.

The number of mammalian species represented in the Limeworks sequence diminishes through the pink and red zones, which evidently record a progressive desiccation, and not, as has been suggested, a drop in the water-table due to recession of the dolomite scarp. The main dripstone layer in the nearby Cave of Hearths was formed during a subsequent pluvial period.

*Taung*³

The Taung skull, type-specimen of *Australopithecus africanus* Dart, was found in December, 1924, during the quarrying of tufaceous limestone at Buxton, 7 miles southwest of Taung on the Transvaal border of Bechuanaland. (See Dart, '25.) It occurred in a pink calcified sand which occupied a tunnel-like cave about 50 feet below the surface in the limestone (pl. 1). The Buxton limestones are tufas built up by springs and streams issuing from the dolomite escarpment which forms the western margin of the Harts valley (tributary of the Vaal). There are three separate masses of tufa at Buxton, formed at different times. The *Australopithecus* cave was in the oldest mass, which is harder and less cellular than the later masses, and has a maximum thickness of 70 feet. The cliff against which it is banked could barely have come into existence before the time that the Vaal river was beginning to cut down into the sub-Karoo surface, a stage which was marked by the deposition of the Older Gravels (Cooke, '46, 249). Since the Basal Older Gravels are attributed to the first pluvial and in their upper parts contain pebble-tools, it appears unlikely that any of the Buxton tufas and still less their contained cave deposits can be older than Kageran. Moreover, it is probable that the tufas were laid down when

³ Taung, not Taungs is now the spelling officially approved, for example on maps of the S. African Trigonometric Survey.

the rainfall was higher, or at any rate less erratic than at present, i.e., under conditions that are generally called pluvial. The factors involved in the formation of calcareous tufas are still not fully understood, but the precipitating action of mosses and other plants is suspected of playing an important part (Young, '25, 58; Macfadyen, '28). Tufa is still forming around some springs in the Taung district, but on a very limited scale. The tufa masses at Buxton (and at Thoming, 6 miles to the south) are of such vast extent that they were clearly formed at a time when the springs and streams issuing from the escarpment were more copious than they are today. The average annual rainfall at Taung is now about 17 inches, but owing to its irregularity and the high rate of evaporation the region verges on the semi-arid, "dust-devils" are commonly seen there and constant vigilance is needed to prevent the development of dust-bowls. Although the Buxton tufas contain pockets of sand, their remarkable purity and freedom from *disseminated* quartz grains show that wind-blown sand was very infrequent during their deposition.

The material originally filling the *Australopithecus* cave consisted of fine red sand of aeolian origin. Remains of 14 species of mammals were found in it, including a rodent-mole and a rock-rat closely related to forms now found in desert areas with a rainfall of less than 6 inches (Broom and Schepers, '46, 29). Although Broom inclined to regard the Taung fauna as Pliocene in view of the fact that all the species and 5 of the 14 genera appeared to be extinct, he pointed out that the presence of *Parapapio*, closely approaching the modern *Papio*, was more consistent with its being Pleistocene. Now that the geological evidence is seen to indicate that the containing tufa represents a time of increased rainfall not earlier than Kageran, and that the cave itself was filled under arid conditions, it becomes highly probable that *Australopithecus* of Taung lived during the period of reduced rainfall which in many parts of Africa marked the end of the Kageran, i.e., during the Kaiso stage of some authors. The fact that none of the Taung species has been found at Sterkfontein or Maka-

pan may be a reflection of a difference in biotope rather than of age (Cooke, '52, 33).

The indications are that all three belong to the Kageran, and that the Makapan is older than the other two.

There is no significant difference between the fluorine content of the *Australopithecus* skull and that of bone from a nearby Late Pleistocene (Middle Stone Age) breccia: both contain *circa* 1.0%. As calcite matrices are now known to be barriers to the passage of fluorine ions,⁴ the F-dating method is of small value in these deposits, but if the age-difference between these bones had been of the order of half a million years or more (implied by Broom's dating of *Australopithecus* as Upper Pliocene or older), one would, nevertheless, have expected to find an appreciable difference in their fluorine contents.

Sterkfontein

The main breccia at Sterkfontein, 10 miles n.n.w. of Krugersdorp, has yielded remains of about 16 individuals of *Australopithecus* (*Plesianthropus*) *transvaalensis* Broom. The breccia was apparently accumulated under conditions considerably drier than those of today, judging by its bright pink coloration (which is indicative of the state of oxidation of the iron on the constituent sand grains), and by its mineral composition compared with that of the modern soil (Cooke, '38, 207). The species of *Parapapio* characteristic of the grey zone with *Australopithecus* in the Makapan caves is considered by some investigators to be identical with *P. bromi* from the main Sterkfontein breccia (Cooke, '52, '33). This suggests a broad equivalence in age, but since the Sterkfontein breccia was apparently accumulated under conditions of greater aridity it is probably slightly younger. Although Makapan is now situated in bushveld (savannah) and Sterkfontein in open high veld, the rainfall normals of the two localities do not indicate that at the present-day the Sterk-

⁴ Radioactivity tests kindly carried out for me by Dr. D. J. Simpson of the Geological Survey of South Africa indicated that the same is probably true of uranyl ions (uranium like fluorine accumulates in fossil bones, but through replacement of calcium in the apatite lattice).

fontein area (28 inches at Kromdraai) is notably drier than Makapan (25 inches at Potgietersrust).

The author's conclusion regarding the relative ages of the australopithecine deposits at Makapan and Sterkfontein is supported by the fact that the species of *Crocota* represented at the former (*C. cf. brevirostris*) is of a more archaic type than that at Sterkfontein (*C. cf. spelaea?*). See Broom and Schepers, '46, 75-83; Broom, Robinson and Schepers, '50, 72-75; Toerien, '52.)

Swartkrans

Excavations in a breccia on the Swartkrans kopje (pl. 2) three-fourths mile w.s.w. of the Sterkfontein Caves, have produced fragmentary remains of about 35 individuals of *Australopithecus (paranthropus) crassidens* Broom and at least two of the form "*Telanthropus capensis*" Broom and Robinson. The breccia was accumulated in a cave (formed partly by solution, partly by collapse) whose roof has since been removed by denudation. The sequence of deposits in the Swartkrans cave has been worked out by J. T. Robinson, in collaboration latterly with C. K. Brain who has studied their petrography. The *Australopithecus* breccia (*P*) shows no stratification, has a maximum thickness of nearly 20 feet, is brownish-pink in color, and is heavily calcified. Its sandy residue has approximately the composition of the modern dolomite soil, but judging from the percentage of wind-worn and far-travelled sand-grains in it, this breccia was formed when conditions were slightly drier than today. It is succeeded by a well-stratified breccia (*B*), brown in color with a lower carbonate content, and a declining percentage of wind-worn sand grains. This later breccia was evidently accumulated at a time when the rainfall was increasing to a level exceeding the present-day normals. The fauna of the *Australopithecus* breccia itself is a fairly large one, including a semnopithecine monkey (indicating trees), the baboons *Papio* and *Simopithecus*, and a species of *Equus* (particularly noteworthy, for in the *Australopithecus* deposit at Makapan a

form of *Hipparion* occurs to the apparent exclusion of *Equus*). The presence of shells of *Achatina* in the breccia at Swartkrans is an indication that at the time of accumulation the rainfall was at least dependable. Considering all the evidence, there seems little doubt that the Swartkrans fauna is later than that of Sterkfontein, and that it existed at a time when the climate, although dry, was beginning to change in the direction of increased rainfall. (See Broom and Robinson, '52; Robinson, '52, '53b and forthcoming papers by Robinson and Brain.)

Kromdraai

The type-specimen of *Australopithecus* (*Paranthropus*) *robustus* Broom was found in a loose block of brownish-pink breccia on top of a low kopje at Kromdraai, one mile e.n.e. of the Sterkfontein Caves. Excavation at the site yielded the mandible of a young individual, but no associated fauna. The so-called "Kromdraai fauna," which includes in addition to some archaic types, *Equus kuhni*, *Papio*, *Simopithecus* and *Crocota spelaea*, occurs in brownish breccia exposed about 70 yards away, and is comparable with the fauna of an early stage of the Kamasian pluvial (Olduvai I-II). The brownish color of the Kromdraai breccias (probably all of broadly the same age)⁵ indicates that they incorporated dolomite soil produced under conditions of higher rainfall than those obtaining when the bright pink of Sterkfontein was being formed. Petrographic analysis of the matrix of the Kromdraai skull should eventually establish its age relative to the breccia containing the main Kromdraai fauna. (See Broom and Schepers, '46, 119-122; Robinson, '52, 14-17.)

Eyasi

Robinson ('53a) has shown that the maxillary fragment with premolars found in the Laetolil Beds near Lake Eyasi,

⁵ Some of the brown breccias in workings on Bolt's Farm, one and three-quarters miles s.w. of Sterkfontein Caves, are probably of similar age. It was reported that they had yielded australopithecine femora (*Science*, 108: 551, 1948), but more detailed study showed that these bones were machairodont. (*Fide* Prof. C. L. Camp, *in lit.*)

Tanganyika, and named *Meganthropus africanus* by Weinert, is barely distinguishable from the corresponding portion of "*Plesianthropus*" *transvaalensis* of Sterkfontein. The Laetoli Beds have been correlated with Olduvai Bed I (Hopwood, in Leakey, '50, 23), but since their fauna indicates a drier

TABLE 1
Provisional dating of South African Australopithecinae

STAGES		RAINFALL IN S. AFRICA	ASSOCIATED MAMMALIA	SITES OF AUSTRALO- PITHECUS	HUMAN INDUSTRIES IN VAAL
Olduvai I-II	Lower Kamasian	Maximum	<i>Equus</i> and <i>Papio</i>	Kromdraai	Chellean Oldowan and Hope Fountain types
		Increasing	<i>Equus</i> and <i>Papio</i>	Swartkrans	
Kaiso and Omo	Kageran	Minimum	<i>Parapapio</i> <i>broomi</i>	Sterkfontein	(Early Oldowan and Late Kafuan types) ¹
			<i>Parapapio</i> <i>antiquus</i>	and Taung	
		Decreasing	<i>Parapapio</i> <i>broomi</i> and " <i>Pronoto- choerus</i> "	Makapan (Grey Zone)	Kafuan
		Maximum			
		Increasing			

¹ Known as derivative specimens in early Kamasian deposits.

biotope, and since they contain pebble-tools of a more primitive type (Kent, '41, 178), it is possible that they are slightly older and really of about the same age as the Sterkfontein breccia.

DISCUSSION

The author's provisional dating of the Australopithecinae of South Africa, based on the evidence outlined above, is

summarized in table 1. It will be seen that the known specimens fall neatly into an older group (Makapan, Taung and Sterkfontein), and a younger group (Swartkrans and Kromdraai). This grouping corresponds closely with the main morphological similarities and differences between the various forms. Thus it would seem legitimate to regard them as representing two species or species-groups: the earlier and more pedomorphic species-group, typified by *Australopithecus africanus*, ranged through the second half of the Kageran (= Upper Villafranchian), when conditions were becoming increasingly arid in many parts of Africa; while the second, characterized by the larger and more gerontomorphic species, *Australopithecus (Paranthropus) robustus*, lived during the phase of decreasing aridity which marked the beginning of the Olduvai or Kamasian stage.

Were australopithecines tool-makers?

In March of this year, pebble-tools were found for the first time in the Basal Older Gravels on the 200-foot Terrace of the Vaal (Lowe, '53). Since these gravels were accumulated before the end of the Kageran cycle, it now appears evident that tool-making hominids existed in South Africa at the time of accumulation of at least some of the australopithecine breccias. This conclusion would be strongly reinforced if Robinson is correct in his recognition of a species of *Australopithecus* in the implement-bearing Laetolil Beds of East Africa. The question arises as to whether *Australopithecus* may have been the maker of the pebble-tools. The complete absence of pebble-tools (and indeed of any undoubted artifacts) from the australopithecine deposits in the dolomite areas of South Africa cannot be held to disprove the theory that *Australopithecus* was the agent of their manufacture because it is doubtful if any of these deposits, with the possible exception of Taung, represent the living sites of *Australopithecus*; more probably the deposits were formed in the dens of carnivores which preyed on this hominid. (There

are indications that caves were rarely if ever frequented by hominids before they had the use of fire. The doubtful evidence of fire in the *Australopithecus* layer at Makapan is still *sub judice*, and even if confirmed could most readily be accounted for by a natural grass fire outside having ignited inflammable bat-guano at the entrance to the cave — there are in fact records of comparable fires having occurred in recent times.)

There is a greater probability that australopithecines were living contemporaneously with more advanced hominids, and that these latter were responsible for the pebble-tools. As far as I am aware, no pebble-tools have been found in *any* of the numerous cave and fissure deposits in the Transvaal; yet they do occur in gravels on the old floors of the main river valleys of that region. We do not know what distances carnivores would have habitually dragged the carcasses of hominids, but it is unlikely to have been very far. On the evidence available, taking general probabilities into consideration, it may be presumed that whereas the pebble-tool makers mainly frequented the banks of rivers and lakes, the australopithecines were mostly accustomed to foraging in the bushy kloofs, and being ill-equipped for defense, were more frequently the victims of carnivores.

The conclusion that the australopithecines were not the pebble-tool makers, but their related and more backward contemporaries, is supported by two general lines of reasoning. All the known tool-making hominids had larger brains than any of the apes of today. None of the known australopithecine skulls has a cranial capacity undoubtedly exceeding the maximum recorded in recent gorillas (685 cm^3) — although it must be granted that, judged from brain-size relative to body-weight, the australopithecines should probably be ranked rather higher than modern apes. There is no convincing evidence that the later ones (e.g., Swartkrans) were relatively larger-brained than those from the earlier sites (e.g., Makapan) (see Barbour, '49, 134–135; Ashton, '50). It is true that Broom and Robinson ('50, '52) claimed that some of

the more recently found skulls from Swartkrans had capacities exceeding 700 cm³, but these were estimates based on crushed or broken specimens. In any case the Swartkrans species was taller and heavier in build than the earlier forms. Australopithecines might well have been precursors of larger-brained hominids, but if they were already tool-makers early in Kageran times⁶ one would expect to find that they had become larger-brained, both relatively and absolutely, by Kamasian times; for the correlation between culture and cerebral expansion is highly probable.

The probable co-existence of two types of hominid in South and East Africa during Pleistocene times can be paralleled among the pongids in the Congo today. Perhaps even more relevant is Professor von Koenigswald's discovery of skulls and jaw fragments of large-brained hominids (*Pithecanthropus modjokertensis* group) in the Djetis Beds of Java where he also found the teeth and fragmentary mandible of "*Meganthropus palaeojavanicus*," which is regarded by some investigators as closely comparable with the massive-jawed *Australopithecus* of Swartkrans. The Djetis Beds are of Upper Villafranchian age, and therefore broadly contemporary with the Kageran beds of Africa. (See von Koenigswald, '50.)

It may be recalled that a portion of mandible found with the australopithecine material in the Swartkrans breccia was described by Broom and Robinson ('50) as manifestly "human."⁷ (Subsequently, in the monograph on Swartkrans Ape-man, they included it with the specimens referred to the genus *Telanthropus*; but the status of this is regarded by the present author as less certain.) The association of remains

⁶ The earliest known pebble-tools, found in the high terrace gravels of the Kafu and Kageran Rivers in Uganda, date from an early stage in the long Kageran pluvial (Lowe, '52, 28).

⁷ This adjective, clearly not synonymous with "hominid," still lacks scientific definition. Broom and Robinson presumably used it in the sense of "non-australopithecine, approximately congeneric with species of *Pithecanthropus* or *Homo*." Robinson later adopted the term "euhominid," on the basis of the division of the Hominidae into Prehomininae (= Australopithecinae) and Euhomininae proposed by Heberer ('51), but this practice has not gained general acceptance.

of two (or more) types of hominid in a single cave is easily accounted for if the remains represent the food debris of carnivores. Moreover, there is in this case nothing to preclude the possibility that the "human" jaw fragment at Swartkrans represents one of the pebble-tool makers who had strayed into the australopithecine territory.

It is hoped that further exploration of the fissure deposits near Lusaka in Northern Rhodesia in which Dr. Desmond Clark and the author recently found pebble-tools associated with *Papio*, *Panthera* (sp. nov.?) and other mammalia, may lead eventually to the discovery of pebble-tool man. One may recall here, with all due reserve, Dr. L. S. B. Leakey's claim that the fragmentary jaw of *Homo* discovered by him in 1932 at Kanam, in the Victoria Nyanza Province of Kenya, came from beds of Late Kageran age containing Oldowan pebble-tools. (See Leakey, '35, 9 ff. and correspondence in *Nature*, London, 135: 371, 9 March 1935: *ibid.*, 138: 643, 10 Oct. 1936.)

There are a number of good reasons for believing that although the Australopithecinae may not have been tool-makers, they were probably semi-carnivorous, and users of ready-to-hand tools and weapons. (See Dart, '49; Oakley, '51.) Professor R. A. Dart has assembled a number of interesting observations in support of this thesis — the most cogent being the high percentage of baboon skulls with depressed fractures in the Taung deposits. Reconsideration of this evidence is beyond the scope of the present paper; suffice it to say that an alternative explanation of the fractures has been advanced by Jeffreys ('48), who suggested that they were due to attacks of predaceous hyenas.

CONCLUSIONS

According to the author's interpretation of the evidence at present available, it appears that *Australopithecus* was not a tool-maker; nor are the earliest known representatives of the genus old enough geologically to have been ancestors of the first tool-making hominids. It is quite possible that older species of the genus were ancestral to a more progressive

line which evolved into larger-brained, tool-making types ("men" in common parlance); but if so they remain to be discovered — and not necessarily in *South Africa*.

ACKNOWLEDGMENTS

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PLATE 1

EXPLANATION OF FIGURES

Above: Sections of tufa in the Norlim (Buxton) Quarries, Taung, Bechuanaland. The stack of tufa in the foreground, right of center, is adjacent to the site of the *Australopithecus* cave deposit (see below), now destroyed by quarrying. A similar cave deposit, probably of the same age, is still exposed in the mass of tufa on the extreme right, middle distance ("Hrdlička's Cave"). *Photograph by courtesy of The Northern Lime Company, Ltd.*

Below: (Left)—Stratified and consolidated cave deposits at Limeworks Cave, Makapansgat Valley, Transvaal. (So-called Ancient Entrance.)

(Center)—Face of Buxton Quarry in 1924 showing the dark sandy infilling of the *Australopithecus* cave (X), about 20 feet above the base of the white tufa. *Photograph by courtesy of Professor R. A. Dart.*

(Right)—Breccia with secondary travertine at the "*Plesianthropus*" type-site, Sterkfontein.

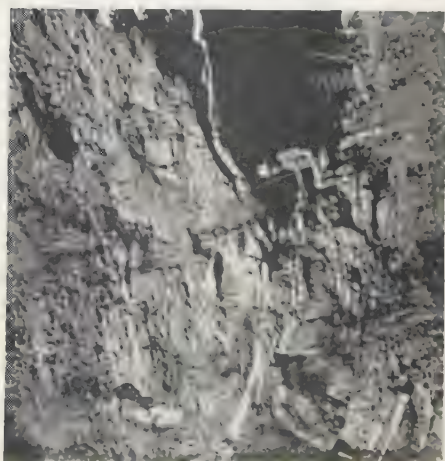
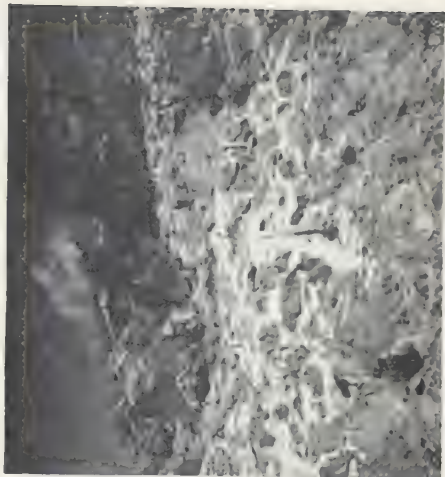
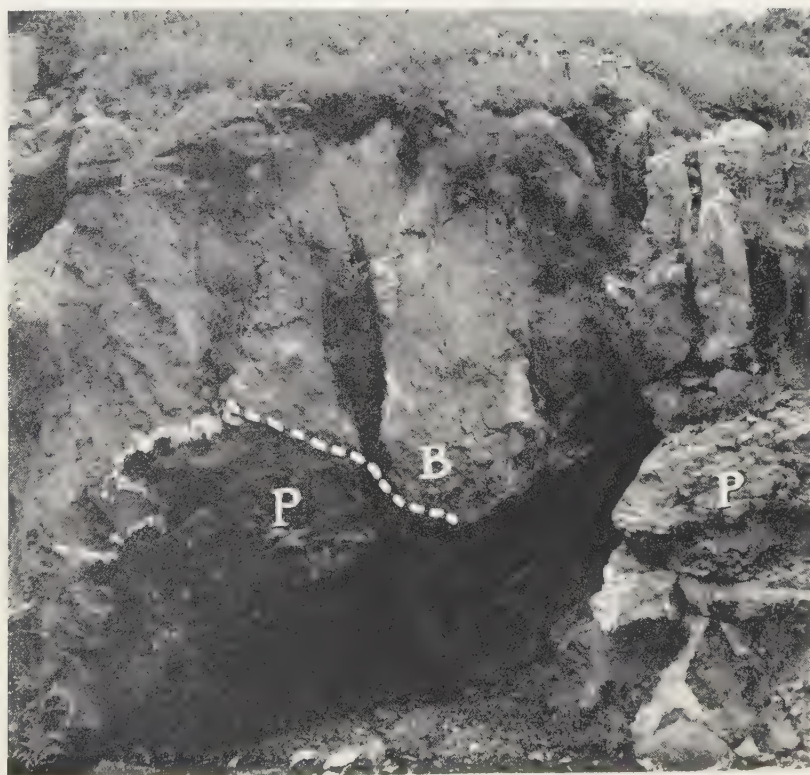


PLATE 2

EXPLANATION OF FIGURES

Above: View of Swartkrans kopje from Sterkfontein. “*Paranthropus*” site indicated by arrow.

Below: Swartkrans cave-deposits: P = Pink Breccia with “*Paranthropus*” remains; B = Brown Breccia. The underlying cavity has been produced by mining of stalagmite (“Basal Dripstone”). Height of section *circa* 10 feet.





A NEW MEDICO-LEGAL JOURNAL.—In the first issue of July-September, 1953, the *Journal of Forensic Medicine* under the editorship of H. A. Shapiro and sponsored by the Medico-Legal Society (Johannesburg), comes into being. Juta & Co., P.O. Box 30, Cape Town, South Africa, are the publishers. According to the announcement, "It will confine its scope to the medico-legal field and will devote its pages to case reports, reviews, abstracts, medico-legal news and the publication of original research work in this increasingly important branch of knowledge and practice."

Contents of the first issue are:

Blood groups and skin colour	M. Shapiro
Identification of skeletal remains	I. Prinsloo
Dentures and individual identification	E. O. K. Harwood
Sudden or unexpected deaths in infancy	K. M. Bowden
X-rays in medico-legal investigation	T. Addison Morgan and M. C. Harris
Sudden death with minimal anatomical findings	L. Adelson
Estimation of stature from the long bones	E. N. Keen
Estimation of age from cranial suture closure	R. Singer

THE ANATOMY OF THE ARTICULAR FOSSA (FOSSA MANDIBULARIS) IN MAN AND APES

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FORTY-FIVE FIGURES

INTRODUCTION

Various features of the temporal bone have been emphasized in discussions of the hominid or pongid affinities of the australopithecine fossils, including the curvature of the upper border of the squamous part, the size of the mastoid process, and the form of the articular fossa and eminence. In a previous paper (Ashton and Zuckerman, '52) we have shown that a frequently-expressed view — that the mastoid process and digastric fossa in most of these fossils is human rather than ape-like — is due to an inadequate appreciation of the development of these characters in the chimpanzee and gorilla. Our own observations suggest that the conformation of these features in the australopithecine skull closely resembles that in the African great apes.

The present paper considers claims that have been made about the hominid character of the australopithecine glenoid cavity. One of the most recent is by Robinson ('52), who writes: "In the Pongidae this is wide and shallow, having no articular eminence but a post-glenoid process occurs which prevents the mandibular condyle from articulating with the tympanic bone. In hominids the fossa is deep and narrow with an articular eminence and a small post-glenoid process closely applied to the tympanic bone, which forms the posterior

wall of the fossa. Among the Australopithecines, skull V from Sterkfontein has a somewhat pongid type of glenoid fossa while all other known specimens, including two others from Sterkfontein, have the hominid type."

In making this statement, Robinson is expressing a widespread belief that an articular eminence is lacking in the great apes; and at the same time he is implying that the human, as opposed to the simian, mandibular condyle articulates with the tympanic bone. In view of some doubt about these matters, it seemed to us worthwhile to examine the whole problem afresh.

MATERIAL AND METHODS

Skulls

The shape of the articular fossa was studied and measured in the skulls enumerated in table 1.

Aging. Skulls were divided into the following age-groups:

	MAN	APES
Infants	1a. Stages up to the eruption of all the milk teeth. 1b. All milk teeth but no permanent molars erupted.	1. Stages up to and including the eruption of all the milk teeth.
Juveniles	2. All milk teeth and first permanent molars erupted.	2. All milk teeth and first permanent molars erupted.
Sub-adults	3. All stages between the eruption of the permanent incisors on the one hand and the permanent third molars on the other.	3. All stages between the eruption of the permanent incisors on the one hand and the permanent canines and third molars on the other.
Adults	4. All permanent teeth erupted.	4a. All permanent teeth erupted, wear not having extended beyond the three lateral cusps of the lower second molar. 4b. All permanent teeth erupted, wear having extended to the medial cusps of the lower second molar.

TABLE 1
Numbers and location of skulls studied

SPECIES	NUMBER	LOCATION
Chimpanzee	182	Powell-Cotton Museum, Birchington.
Gorilla	211	Powell-Cotton Museum, Birchington.
Orang-utan	82	Dept. of Anatomy, University of Birmingham, and Dept. of Mammals, British Museum of Natural History.
Man	94	Depts. of Anatomy, Universities of Birmingham, Cambridge, Leeds and Manchester: University College of S. Wales; The Middlesex Hospital and St. Thomas's Hospital, University of London.
	52	Dept. of Osteology, British Museum of Natural History.
	49	Dept. of Osteology, British Museum of Natural History.
	48	Cambridge University Museum of Archaeology and Ethnology.

Sexing. The sexes of the human skulls were not known, and no attempt was made to determine sex from bony features in view of the known uncertainties of such diagnoses.

The sexes of the chimpanzee and gorilla skulls were known from field records. Males and females of these genera were, therefore, separated. The orang-utan skulls had not been sexed in the field, and adult specimens of this genus were sexed by a qualitative examination of the usual cranial and dental features (Ashton and Zuckerman, '50). Sexual dimorphism is not marked in the skull of the immature orang, and no attempt was made to separate the sexes in each of the first three age groups.

The numbers of skulls in each age and sex subgroup are given in table 2.

Nomenclature. The term "articular fossa" is, for convenience, used to describe the area enclosed within the line of attachment of the capsule of the temporo-mandibular joint; it therefore includes that part of the articular eminence which is within the joint. The term "glenoid cavity," or "mandibular fossa," takes in the articular fossa and extends back to include the anterior face of the tympanic bone as well.

Most standard English texts define the articular eminence as the bony structure which forms the anterior boundary of the articular or mandibular fossa. This description obviates the difficulty of defining the level on the anterior wall of the fossa where the "eminence" begins. On the other hand, unless the word "eminence" is to be restricted to the apex (actually the lowermost point, or point of maximum convexity) of the process in front of the "fossa," it becomes necessary to regard the anterior wall of the fossa as the posterior face of the eminence. In taking this view we are, in effect, merely following Lubosch ('06), the author of one of the most quoted studies of the articular fossa. According to his description, the articular fossa is the posterior boundary of the eminence ("Die hinter dem Tuberculum articulare als vorderer Grenze gelegene Fossa glenoidalis ist mässig tief . . .").

The eminence is sometimes regarded as the equivalent or homologue of the preglenoid process, a lip of bone which in carnivores forms the anterior wall of the joint cavity. In many species belonging to this order the transverse cylinder of the condyle of the mandible fits exactly into the cavity, and in these animals the joint is a perfect hinge, allowing of movement in only one plane (e.g. Parsons, '00). Todd ('30) points out that while the carnivore preglenoid process is the homologue of the primate articular eminence, it is not "its functional equivalent."

No ambiguity attaches to the term "post-glenoid" process or tubercle (according to Lubosch, = processus retrofoveolaris = conus articularis = processus conoides). It is a usual feature in the Eutheria as well as the Marsupialia (Lubosch, '06).

Biometry. Skulls were placed in the craniometer described by Ashton and Pardoe ('50), with the Frankfurt horizontal parallel to the base-line of the machine. The foot of the projector was slotted so that it rode in the vertical arm of a T square which was applied to the base-line of the apparatus. In this way movements of the marker and of the pointer (elongated so as to obviate the marker fouling the base of the skull), were restricted to axes either parallel or at right angles to the Frankfurt plane. Tracings and measurements were made of only one glenoid fossa of each skull, the right and left sides being taken alternately.

The following points were projected on to the recording paper (see fig. 1):

1. The tip of the post-glenoid process.
2. The deepest point of the articular fossa, in the mid-sagittal plane of the fossa.
3. The most posterior point of the articular fossa. In all ape and many human skulls this was for all practical purposes in the same coronal plane as the tip of the post-glenoid process. In some human skulls, however, part of the squamo-tympanic fissure, into which the fibrous capsule of the joint is inserted, lay posterior to the tip of the process.

4. The most anterior point of the joint. This was identified either by an obvious ridge to which the joint capsule had been attached, or by the contrast in texture of bone that had been within or outside the capsule. In human skulls it usually lay anterior to the point of maximum convexity (i.e. the apex) of the articular eminence, and occasionally on the upturned part of the antero-inferior part of the squamous temporal. In

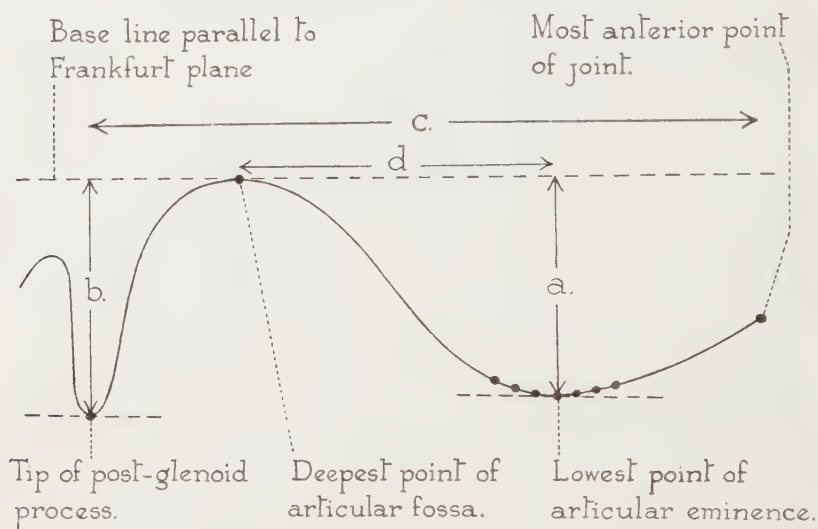


Fig. 1 Schematic sagittal section through the mid-point of the hominoid articular fossa, to show the dimensions examined in this study.

the ape skulls, in which the articular eminence was as a rule slightly less upturned, it usually appeared to extend further forwards.

5. A series of points taken on the mid-sagittal line of the articular fossa, which when connected, defined the contour of the articular eminence as seen in a mid-sagittal section. These points were marked in order to define the point of maximum convexity of the articular eminence.

Measurements. A "base" line was drawn on each record, parallel to the Frankfurt plane, and tangential to the deepest

point of the fossa. The maximum projection of the articular eminence (a) and of the post-glenoid process (b) were measured perpendicular to this line. The overall length of the joint (c) and the distance between the most prominent (lowermost) point on the eminence and the deepest part of the fossa (d) were measured parallel to this base (see fig. 1). Three indices were then computed:

1. $100\ a/c$ —to indicate the prominence of the articular eminence relative to the overall length of the fossa, or alternatively, the degree of antero-posterior “compression” of the fossa.

2. $100\ a/d$ —to give a measure of the tangent of the angle of slope of the posterior face of the articular eminence, and thus of the gradient of the slope over which the mandibular condyle rode during its forward and backward movement. This index, like $100\ a/c$, also provides a measure of the degree of antero-posterior “compression” of the fossa.

3. $100\ b/a$ —which relates the protuberance of the post-glenoid process to that of the articular eminence, with the skull orientated in the Frankfurt horizontal.

Precision of measurement. Measurements were taken with a steel rule, and recorded to the nearest millimeter. One month after they were first studied, tracings and measurements were repeated 5 times on 5 young adult female orang-utan skulls. Analysis showed that in all cases the variance introduced by inconsistencies in measurement was quite insignificant ($P < 0.001$), compared with that existing between skulls.

Statistical analysis. Analysis has been restricted to the computation of means and their standard errors for each dimension of each age and sex subgroup. These are shown in table 2.

As judged by the ratio $\frac{100 \times \text{S.E. mean}}{\text{mean}}$, the statistical estimates are less precise than those generally obtained in craniometric studies of correspondingly large series of specimens. Nevertheless, as table 2 shows, there can be no doubt about the significance of the differences observed between mean values.

TABLE 2

Dimensions and indices of articular fossa in man and apes

SEX	SPECIES	AGE	a			100 a/c			100 a/d			b			100 b/a		
			MEAN	NO. OF OBSERVATIONS	S.E. MEAN	MEAN	NO. OF OBSERVATIONS	S.E. MEAN	MEAN	NO. OF OBSERVATIONS	S.E. MEAN	MEAN	NO. OF OBSERVATIONS	S.E. MEAN	MEAN	NO. OF OBSERVATIONS	S.E. MEAN
♂ + ♀	Man (mixed — mostly modern white)	Infants (1a)	2.2	23	0.15	15.2	23	0.95	39.2	23	3.73	2.0	23	0.21	100.8	22	11.99
♂ + ♀	Man (mixed — mostly modern white)	Infants (1b)	3.5	30	0.19	22.0	30	1.13	50.3	30	2.43	3.9	30	0.22	121.3	30	8.68
♂ + ♀	Man (mixed — mostly modern white)	Juveniles	4.2	26	0.22	24.9	26	1.51	53.5	26	3.82	4.0	26	0.18	98.7	26	5.14
♂ + ♀	Man (mixed — mostly modern white)	Sub-adult	5.1	15	0.23	28.0	15	1.29	59.5	15	2.81	4.7	15	0.30	97.0	15	10.97
♂ + ♀	Man (British Spitalfields)	Adult	7.4	48	0.20	35.6	48	1.04	82.9	48	3.35	4.9	48	0.24	68.0	48	2.80
♂ + ♀	Man (West African)	Adult	6.7	52	0.17	32.0	52	0.95	74.1	51	2.81	5.2	52	0.20	79.6	52	3.36
♂ + ♀	Man (Australian aboriginal)	Adult	6.7	49	0.22	32.8	48	1.11	67.3	49	2.84	4.5	49	0.21	77.5	49	4.32
♂	Chimpanzee	Infant	1.8	6	0.54	13.7	5	2.63	26.7	5	6.37	4.0	6	0.78	200.0	5	35.40
♂	Chimpanzee	Juvenile	3.6	15	0.24	17.6	15	1.11	35.0	15	1.99	4.7	15	0.29	135.0	15	9.49
♂	Chimpanzee	Sub-adult	3.4	16	0.22	15.3	16	0.99	30.4	16	1.99	4.1	16	0.34	126.8	16	14.30
♂	Chimpanzee	Adult (4a)	3.7	17	0.30	13.7	17	1.19	26.2	17	1.95	3.5	17	0.40	112.7	17	16.70
♂	Chimpanzee	Adult (4b)	3.6	13	0.45	12.9	13	1.57	23.1	13	2.07	4.3	12	0.48	131.5	12	15.50
♂	Chimpanzee	Infant	3.3	8	0.31	19.8	8	1.76	36.5	8	3.42	4.3	8	0.25	143.8	8	20.70
♂ + ♀	Chimpanzee	Juvenile	3.0	11	0.23	15.2	11	1.27	29.4	11	2.85	4.7	11	0.30	170.5	11	20.64
♂ + ♀	Chimpanzee	Sub-adult	3.4	15	0.31	14.8	15	1.25	31.9	15	2.75	4.2	15	0.42	139.9	15	17.11
♂ + ♀	Chimpanzee	Adult (4a)	3.5	49	0.15	13.5	49	0.58	24.2	49	0.92	3.7	49	0.22	112.6	49	9.11
♂ + ♀	Chimpanzee	Adult (4b)	3.9	32	0.16	15.0	32	0.59	29.0	32	1.46	3.8	32	0.24	103.1	32	7.23
♂	Gorilla	Infant	3.5	12	0.54	22.3	10	1.78	45.8	10	2.63	6.1	12	0.48	157.8	10	16.78
♂	Gorilla	Juvenile	5.1	11	0.41	22.7	11	1.99	51.7	11	4.17	7.2	11	0.40	152.1	11	15.96
♂	Gorilla	Sub-adult	5.8	9	0.28	19.6	9	1.01	45.7	9	3.05	7.3	9	0.37	129.0	9	8.23
♂	Gorilla	Adult (4a)	7.3	37	0.29	21.2	37	0.78	43.9	37	1.70	9.1	37	0.37	131.1	37	7.13
♂	Gorilla	Adult (4b)	8.0	38	0.34	21.7	38	0.91	44.7	38	1.96	9.6	38	0.39	124.9	38	5.83
♂	Gorilla	Infant	3.9	7	0.55	21.6	7	3.12	43.7	7	5.31	5.4	7	0.57	154.5	7	21.37
♂ + ♀	Gorilla	Juvenile	4.7	10	0.30	24.3	10	2.09	50.4	10	5.35	5.8	10	0.42	128.3	10	13.08
♂ + ♀	Gorilla	Sub-adult	6.0	22	0.26	22.9	22	1.17	52.0	22	2.80	7.3	22	0.43	124.0	22	6.78
♂ + ♀	Gorilla	Adult (4a)	6.5	41	0.25	21.9	41	0.84	48.2	41	1.70	9.1	41	0.36	145.1	41	6.90
♂ + ♀	Gorilla	Adult (4b)	6.7	24	0.29	22.3	24	0.86	46.0	24	1.47	8.6	24	0.56	133.4	24	10.69
♂ + ♀	Orang-utan	Infant	2.7	7	0.29	18.9	7	2.06	36.8	7	4.03	4.9	7	0.46	192.9	7	29.96
♂ + ♀	Orang-utan	Juvenile	3.0	6	0.37	15.4	6	1.93	29.2	6	3.36	5.2	6	0.48	187.5	6	31.46
♂ + ♀	Orang-utan	Sub-adult	2.8	6	0.40	13.0	6	2.51	34.5	6	8.15	4.2	6	0.60	168.1	6	33.65
♂	Orang-utan	Adult (4a)	3.3	9	0.50	11.7	8	1.08	27.2	8	3.43	5.3	9	0.62	152.7	8	19.71
♂	Orang-utan	Adult (4b)	4.4	28	0.25	13.3	28	0.72	30.9	28	1.68	4.6	28	0.30	138.0	27	26.57
♂	Orang-utan	Adult (4a)	3.2	18	0.25	12.8	18	1.06	32.9	18	2.25	4.9	18	0.37	188.3	18	31.38

RESULTS

General description. In both man and the apes the glenoid cavity is formed by the squamous temporal and the tympanic bone, the posterior wall of the fibrous capsule of the temporo-mandibular joint being attached to the fissure where the two meet (laterally the squamo-tympanic fissure; medially and sometimes, the petro-tympanic and petro-squamous fissures). When the post-glenoid process is well developed the squamo-tympanic fissure lies between the lower border of the process and the tympanic plate, and the capsule becomes partly attached to the lower border of the process. Where the process is so well developed as to project below the lower margin of the tympanic bone (e.g. in adult great apes and monkeys) the posterior part of the capsule is attached to the lower margin of the process.

The main difference between the articular fossa in man and the apes lies in the fact that the human fossa is usually deeper and narrower, and therefore better defined, in keeping with the more antero-posteriorly compressed and slenderer condyloid process of the mandible. As part of this difference, the articular eminence is also very much better marked. Conversely, the medial glenoid process is usually much better marked in the great apes, and particularly in the gorilla, where it may project downwards as a flange-like process of the most medial part of the squamous temporal, completely separate from the spine of the sphenoid (cf. fig. 33, where the medial glenoid process can be seen medial to the post-glenoid process). In man, and in some chimpanzees and orangs (e.g. figs. 20, 21, 30), the medial articular lip usually runs smoothly into the postero-lateral extremity of the sphenoid. The latter not infrequently projects downwards as a sharp and sometimes very pronounced spine (spine of the sphenoid: e.g. figs. 10 and 24), which is occasionally perforated by the middle meningeal artery on its way into the true foramen spinosum. This appearance of perforation can be explained as being due to the presence of a sphenoidal spine in its usual position postero-lateral to the foramen spinosum, and of another spinous process with its base between the

foramina ovale and spinosum, and which fuses with the true spine of the sphenoid below the foramen spinosum. This double spine may be connected by a bar of bone (the ossified pterygo-spinous ligament), which passes over the foramen ovale to the base of the lateral pterygoid plate.

Sicher ('51) notes that the medial articular lip in man is "sometimes elevated to a triangular process," which he calls the "temporal spine." We ourselves have seen human skulls in which the lip projects as a flange separate from the spine of the sphenoid (e.g. fig. 10).

Like the medial glenoid process, the posterior articular lip, which laterally forms the post-glenoid process, is also, as a rule, very much better developed in the chimpanzee and gorilla than it is in the human skull. In man, the process usually extends downwards for a short distance, and shuts out only the upper part of the lateral extremity of the tympanic bone from the glenoid cavity (e.g. figs. 2 to 10). In adult male gorillas, chimpanzees and oranges, it usually projects downwards to below the lower level of the tympanic bone (e.g. figs. 29 to 37). The process is as a rule better developed in older than in younger animals (cf. figs. 11 to 19 with figs. 20 to 37), in which the relation of the post-glenoid process and tympanic plate is much the same as it is in adult human skulls (e.g. figs. 5 to 10). In the adult gorilla the process almost always forms the lateral third (and even half) of the posterior wall of the glenoid cavity, the medial half being formed by the tympanic bone. Occasionally a gorilla skull may be encountered in which the process is so well developed as to exclude the tympanic bone completely from the posterior wall of the glenoid cavity (e.g. fig. 34). Conversely, one sometimes comes across an adult chimpanzee or gorilla skull in which the post-glenoid process covers only about the upper two-thirds, or half, of the lateral part of the bone (e.g. figs. 21, 23, 38, 40). Similarly, one sometimes finds a human skull with a very well-developed process (e.g. figs. 10, 42, 44). In general the external auditory meatus is relatively smaller and less funnelled in apes than in man,

and this helps to emphasize the greater prominence of the post-glenoid process in these creatures.

The degree of actual fusion of the posterior face of the process with the anterior surface of the tympanic plate varies from skull to skull, and in our experience more usually in inverse proportion to the degree of development of the process.

Particular interest attaches to descriptions of the articular eminence in man and apes. It is often said that the eminence is not present in infants and young children, and that it only begins to develop at about the age of six years (e.g. Lubosch, '06; Humphreys, '32). It is also usually said, or implied, that there is no articular eminence in the great apes (e.g. Lubosch, '06; Richter, '19; Le Gros Clark, '47; Robinson, '52). These statements do not fit the facts. An articular eminence, in the sense of a development of bone whose posterior face forms the anterior sloping wall of the glenoid cavity, and which represents the anterior or medial root of the zygomatic arch, occurs both in apes and man, and is present from infancy onwards. In man the anterior face of the eminence, i.e. the antero-medial extremity of the squamous temporal is, as a rule, more upturned than it is in the apes, in conformity with the antero-posterior compression of the whole eminence.

The position of the anterior and lateral limits of attachment of the fibrous capsule of the joint which, in many specimens, is plainly marked by a distinct osseous ridge, appears to be very variable in the human skull. In some the joint reaches forward to the anterior border of the anterior root of the zygomatic process (with the skull viewed in *norma basalis*). In a few it extends forwards beyond this, almost on to the upturned anterior and inferior part of the squamous temporal in the infratemporal fossa. In others it does not even reach the anterior margin of the anterior root of the zygomatic process.

From the point of view of comparison the important fact is that pronounced variations occur in the depth and contour of the articular fossa both in man, as has long been recognized, and — what does not appear to have been properly appreciated — in the apes as well (plates 1 to 5). The problem, therefore,

is that of finding a method for expressing the variations which occur in the prominence of the eminence, and of other features of the glenoid cavity which, from the point of view of its bony constitution, is otherwise identical both in man and apes.

Quantitative assessment of shape of articular fossa. It was not easy to devise a satisfactory series of indices to lend precision to these general observations. As indicated in the section on methods, the projection of the articular eminence and of the post-glenoid process was measured in relation to the deepest (i.e. uppermost) point of the articular fossa. The antero-posterior compression of the fossa was measured in terms of indices which relate the prominence of the articular eminence to the antero-posterior length of the articular fossa and which also give a measure of the gradient of its posterior face. Table 2 provides a summary of our quantitative observations.

The prominence of the articular eminence (measurement "a"). An articular eminence is present at all ages in both men and the great apes. It is larger in adults than in infants, the growth change being particularly marked in man and in the gorilla. Sex differences are conspicuous in the adult gorilla. They are hardly obvious in the orang or chimpanzee.

The absolute height of the human articular eminence agrees closely with that of the gorilla and is much larger than in the chimpanzee or orang-utan. Since the overall length of a mature chimpanzee or orang skull is, if anything, greater than that of a human skull, this means that the human articular eminence is relatively more prominent than the absolute measurements suggest. In view of the greater size of an adult male gorilla skull, one could equally assume that the human eminence is relatively more prominent than even in the male (but not female) gorilla, in spite of the similarity in absolute measurements.

The antero-posterior "compression" of the articular fossa (indices 100 a/c, 100 a/d). The figures bear out the qualitative observation that the articular fossa is far less compressed, and the slope of the eminence less steep in young than in adult

human skulls. Corresponding age changes are not apparent in any of the great apes.

Sexual differences in this feature are not marked in any of the apes.

The figures also bear out very strikingly the fact that the articular fossa in man is much more compressed than in the apes (e.g. a $\frac{100a}{c}$ index of 32 to 36 in adult man as compared with one of 12 to 24 in adult apes, and a $\frac{100a}{d}$ index of 67 to 83 in adult man as compared with one of 23 to 48 in adult apes. In young human skulls the measure of compression is much the same as in apes of a corresponding age — but, as already noted, the degree of compression does not increase as the ape ages.

The projection of the post-glenoid process (measurement b and index 100 b/a). The absolute height of the post-glenoid process is practically the same in man, the chimpanzee and the orang, and only about one-half what it is in the adult gorilla. In all three apes the process is much broader and thicker than in man, and at all ages studied it is more protuberant, relative to the articular eminence, than in men of corresponding stages of development (cf. plate 1 with plates 2, 3 and 4). Furthermore, relative to the overall size of the skull, the process in the gorilla can be regarded as being even more prominent than its absolute height suggests. A further well-known distinction lies in the fact that in man the post-glenoid process sometimes fuses with the upper part of the tympanic bone, so that the lateral part of the posterior wall of the glenoid cavity consists of a face of bone comprising squamous temporal above and tympanic plate below. In the apes the post-glenoid process as a rule remains quite distinct from the tympanic, although fusion does sometimes occur (e.g. figs. 23, 26, 31, 37).

Sexual differences in the degree of projection of the process are not pronounced in any of the three apes. The absolute height of the post-glenoid process increases with age in man and the gorilla, but our figures fail to bring out this growth change in the chimpanzee or orang. On the other hand, the fact that the index $\frac{100b}{a}$ decreases with age in all four species (and not only in the orang and chimpanzee, which fail to ex-

hibit any very obvious age changes in the absolute projection of the post-glenoid process) implies that the articular eminence grows relatively more than the post-glenoid process, both in man and the apes, during the course of maturation of the skull.

DISCUSSION

It is clear from our observations that there are no qualitative features by which one can sharply differentiate the human and anthropoid glenoid cavity or articular fossa. There is, for example, no foundation for the view that an articular eminence is a distinctive hominid characteristic, and one which is generally lacking in the anthropoid apes. Even the two other features which have the greatest claim to being diagnostic characters of this kind — the relations of the post-glenoid process to the tympanic plate and the degree of development of the medial articular process — differ, as between man and the apes, in the degree of their expression rather than in some particular structural way. For example, as already observed, one comes across chimpanzee skulls in which the medial articular process runs smoothly into the inferior surface of the lateral part of the great wing of the sphenoid, and into the spine of the sphenoid; and conversely, one finds human skulls in which the medial articular lip projects as a free process. Similarly, while the post-glenoid process is, as a rule, very much bigger in apes, one may come across chimpanzee and human skulls in which the relative development of the process is about equal.

Prevailing misconceptions about some of these matters seem to derive, partly if not wholly, from Lubosch ('06), whose views about the anatomy of the articular fossa in apes are hardly as well founded as those he stated for man. His main observations were based on a selected series of 300 human skulls that had been gathered to demonstrate various unusual conditions (e.g. Wormian bones, asymmetry, etc.). Lubosch correctly described, and confirmed, the considerable variations that occur in the size and shape of the human articular eminence and fossa, as well as in the post-glenoid process, and pointed out that in these characters no two skulls are alike. He

also reported, without giving many details, that the articular eminence is absent or at best very poorly marked in infants, and that juvenile skulls usually possess a low rather than a high articular process. He observes, too, that relatively more adult female than male skulls have a low or flat eminence. Instead, however, of regarding the height of the eminence in different skulls as forming a continuous series of measurements, he went on to divide them arbitrarily into "high," "normal" and "flat" groups, to which he proceeded to attach ontogenetic and phylogenetic significance. The low eminence in infants he equated with what he regarded as the usual condition in apes and in "diluvial" fossil man; and height variations in adult man he regarded as being related to degrees of orthognathism and prognathism — a high eminence going with an orthognathous skull.

Lubosch's views about the articular eminence of apes were based on an examination of 6 orang-utan, 3 gorilla, and 2 chimpanzee skulls. One of the latter is said to have been that of an infant with milk teeth, and with an articular eminence which corresponded exactly with that of a 9-month-old human baby. The other skulls were presumably adult specimens; none is said to have had an articular eminence as high as is usual in modern man. In these respects Palaeolithic and Neolithic man were presumed by Lubosch to have occupied an intermediate position, or to have been more simian than human.

Lubosch's final conclusion, based on an analysis of the relative size of the molars, was that the contrast between high and low articular eminences reflected differences in dentition — the ape being able to slide its lower under its upper teeth without lowering the mandible, whereas in man the mouth must be opened to allow this to happen. What we cannot gather from his account is whether he attached any "evolutionary" or functional significance to the differences between "flat," "normal" and "high" articular eminences in the modern skulls he studied. Equally, it is difficult to see what ontogenetic or phylogenetic, or indeed functional significance, Lubosch attached to the fact that the articular fossa was shallow, and the

eminence small (i.e., tending towards the ape-like condition) in women and in children. His conclusions would in all likelihood have been completely different if, instead of defining three arbitrary groups, he had treated his measurements of the eminence as constituting a continuous series, with probably a normal variation.

Richter ('19), in attempting to compare the mandibular mechanism of man and monkeys, also started from the belief that monkeys and apes lack both an articular cavity and an articular eminence. He did, however, try to check the inferences he drew from an analysis of cranial features by observation of living animals. So where Lubosch affirms, as an inference from cranial and dental features, that the ape can move its mandible only vertically and forwards, and never in the horizontal plane, thus precluding grinding movements, Richter states that the animal is an "oblique" chewer. Movements of the mandibular condyles alternate with each other either in an anterior or posterior direction but, because of the presumed lack of an articular fossa and eminence, not vertically. Correspondingly the right and left teeth alternate in their movement and action, and in this way the ape or monkey is able to carry out lateral grinding movements of the jaw. According to Richter the presence of the canines restricts the lateral movements to the width of about half a tooth.

This picture, which is nearer to the truth than the one drawn by Lubosch, was to some extent elaborated by Petrovits ('30a, b). Petrovits confirmed that the newborn baby does not have an articular eminence, which according to him begins to develop at about two months post-partum and, with considerable individual variation, is usually completed in about two years. He also emphasized the considerable individual variation there is in the form of the articular fossa, at the same time confirming the correlation of a small articular eminence with a shallow fossa. He does not, however, accept Lubosch's theories about orthognathism and prognathism, but refers to other factors as affecting the size of the eminence. For example, small people usually have a shallow fossa and a low eminence; and a power-

ful dentition and strong set of masticatory muscles are associated with a better-developed articular eminence. Loss of teeth, as occurs in aged people, is correspondingly associated with a regression of the eminence. Petrovits then repeats the observation that apes, Palaeolithic and Neolithic man have a shallow articular fossa and a very small eminence, and he cites observations of his own to support the view that these characters in the newborn baby illustrate the phenomenon of neoteny, insofar as they correspond to the simian condition.

Todd ('30) appears to have been the first to depart sharply from this description of the articular fossa and eminence in the ape. Thus he points out that in addition to a well-marked post-glenoid process in the ape, there is a "strikingly developed" articular eminence in front of a poorly-marked articular fossa. He refers to the individual variability of the articular fossa and eminence in the chimpanzee and gorilla, and makes a point of the fact that apes can, and do, grind their teeth. "Antero-posterior movements and lateral molar movements, circumferential to a point not far behind the incisors, are quite possible and the occlusal facets demonstrate their existence." He goes on to say that "In the Anthropoid the important dental feature is occlusion of teeth for trituration," and that "The snapping action of the jaws associated with the long narrow muzzle of Carnivores is unthinkable in Anthropoids."

Fairly similar views, based on an analysis of the skull in man and apes, were independently reached by Žlábek ('30), who begins by emphasizing the weakness of inferences about jaw action which are based upon cranial studies alone. Žlábek, who believed that it is only the first phase of the lowering of the jaw that can be properly inferred from a study of the skull, classifies the temporo-mandibular joint in man and the apes as belonging to a group of non-specialized universal joints, permitting of movements in the horizontal as well as vertical planes. He points out that vertical movements are common to all mammals, but that in carnivores all other types of movement are eliminated, the temporo-mandibular articulation becoming "monofunctional." The joint has the same anatomical

constitution in man and apes, and Žlábek cites Riegner's ('06) observation that the lateral pterygoid muscle has the same form and the same function in man and monkeys. The exact shape of the fossa and eminence varies between different apes, but in general the articular cavity is not as deep as it is in man. Žlábek takes issue with Lubosch about the occurrence of an eminence, and here he refers not only to his own observations, but to certain others reported by Jacoby ('03). Another observation of Žlábek's that is worth citing is that in many apes the articular disc is attached behind to the post-glenoid process.

It is clear, therefore, that we are not the first to draw attention to the fact that Lubosch's description of the articular fossa and eminence in the ape is incorrect. This is not to say that these features are identical in man and ape — our observations show clearly enough that differences do, in fact, exist. The important point is that there is no foundation to the view that among the Hominoidea the articular eminence is a peculiar hominid character. Other differences between the articular fossa of man and apes, e.g. the relative position of the temporo-mandibular joint in the skull (von Haussen, '31), could also be pointed out, but they are not relevant to the present discussion.

A significant feature brought out by our study is that the articular fossa in the young human skull is no more compressed than it is in the ape skull of corresponding age. Here, in effect, we have merely confirmed Petrovits' ('30b) observation. The difference between the fossa in adults is essentially due to the fact that in the ape growth appears to take place in all directions, whereas in man relatively less growth occurs in the antero-posterior axis of the fossa than in other directions.

As has already been observed, the contour and area of the articular fossa (by which we mean here not only the summit of the fossa, but also its posterior and anterior faces), varies from skull to skull not only in man but also in apes. The shape, size and thickness of the articular disc varies in conformity with this variation. When the jaw of a monkey is shut, the posterior fibrous part of the articular disc (cf. Retterer and Neuville, '20; Žlábek, '31) is vertically disposed against the posterior

articular lip, i. e. the anterior face of the post-glenoid process. When the jaw opens, the articular disc is pulled forwards, and at the same time the angle between the posterior vertical and superior horizontal part of the disc tends to straighten out. This change can be easily demonstrated in dissections of monkey heads, and presumably it also occurs in the temporo-mandibular joint of an ape or human skull in which the post-glenoid process is well developed.

It is obvious that the view that the articular fossa in most of the australopithecine fossils resembles the human rather than the anthropoid condition is to a certain extent based upon a misconception about the nature of the articular fossa in the ape (e.g. the idea that an articular eminence is usually lacking in these animals. See statement by Robinson, quoted on p. 29 above). It is difficult to determine from the published descriptions the exact condition of the fossa in the different specimens.¹ We have attempted to determine what the position is by examining such plaster casts of the australopithecine fossils as are available in the British Museum of Natural History (*Paranthropus crassidens*; *Paranthropus robustus*; *Plesianthropus transvaalensis*). Judging by these specimens, there seems little if any reason to suppose that the condition of the australopithecine articular fossa is materially different from that found in the African great apes. For example, the fossa in *Paranthropus robustus* is far bigger and less compressed than it is in a typical human skull, and as open as one would expect to find it in, for instance, a gorilla. We have attempted to measure the degree of compression in this specimen as well as in *Plesianthropus transvaalensis*, but as casts only have been available to us, we cannot be sure that we have been able to identify correctly such points as the anterior limit of the articular fossa, or the point of maximum convexity of the ar-

¹ Descriptions of the mandibular fossa are provided on the following pages of the official accounts of the fossils: *Plesianthropus transvaalensis* — Broom and Schepers ('46), p. 50; Broom, Robinson and Schepers ('50), pp. 18, 21, 26, 28. *Paranthropus robustus* — Broom and Schepers ('46), p. 89. *Paranthropus crassidens* — Broom and Robinson ('52), pp. 10, 13, 15, 28, 29.

ticular eminence; nor can we be certain that the casts accurately reproduce the size and disposition of the post-glenoid process. Subject to these shortcomings, the two measurements and three indices of the articular fossa of *Plesianthropus* are all well outside the human range, but fall between the chimpanzee and gorilla. The figures for *Paranthropus robustus* also agree more with the gorilla than with man. On the other hand, those of *Paranthropus crassidens* appear to correspond more to the human values than they do to those of the apes. It is doubtful if any significance can be attached to this finding in view of the fact that in the specimens concerned the temporal bone and glenoid fossa were "considerably crushed." Broom and Robinson ('52) deemed it "unwise to give any detailed description owing to the crushing" — which one may presume considerably altered the dimensions of the structures related to the glenoid cavity.

SUMMARY

1. A qualitative and quantitative study has been made of the differences between the main features of the articular fossa in human and ape skulls. Two hundred and forty-three human, belonging to 4 different series, 182 chimpanzee, 211 gorilla, and 82 orang specimens were examined.

2. There are no qualitative features by which the human and anthropoid glenoid cavity or articular fossa can be sharply differentiated.

3. The main difference between the articular fossa in man and apes lies in the fact that the human fossa is usually more compressed, i.e. deeper and narrower, than the simian fossa. As part of this difference, the human skull has a better marked articular eminence than the simian skull. An eminence is, however, a distinctive feature in apes, and one which can be observed both in juvenile and adult specimens.

4. Sex differences in the prominence of the eminence are conspicuous in the adult gorilla, but not in the orang or chimpanzee.

5. The absolute height of the post-glenoid process is practically the same in man, the chimpanzee and the orang, and about one-half what it is in the adult gorilla.

6. Occasionally human and ape skulls may be encountered in which the disposition of the post-glenoid process in relation to the tympanic bone is the same.

7. An examination of plaster casts provides little reason for supposing that the condition of the australopithecine articular fossa is materially different from that found in the great apes.

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PLATES

PLATE I

EXPLANATION OF FIGURES

Variation in the development of the post-glenoid tubercle of man. Small, intermediate and well-developed examples of each type are illustrated.

2, 3, 4 Immature, mixed stock.

5, 6, 7 Adult, Anglo-Saxon.

8, 9, 10 Adult, Inca.

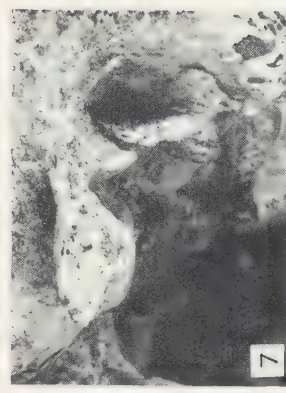
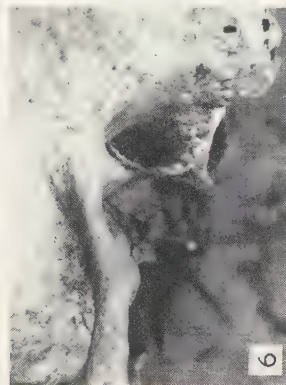
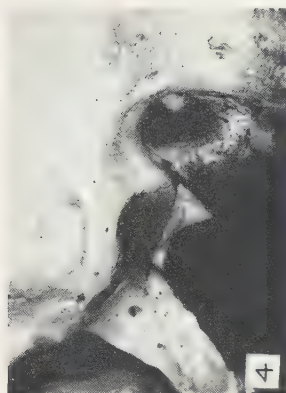


PLATE 2

EXPLANATION OF FIGURES

Variations in the development of the post-glenoid tubercle of immature apes. Small, intermediate and well-developed examples of each type are illustrated.

11, 12, 13 Chimpanzee.

14, 15, 16 Gorilla.

17, 18, 19 Orang-utan.

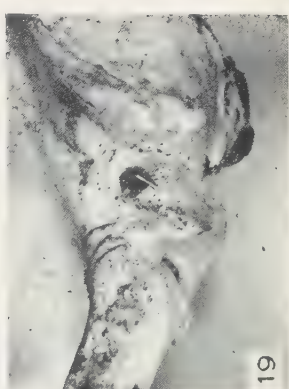
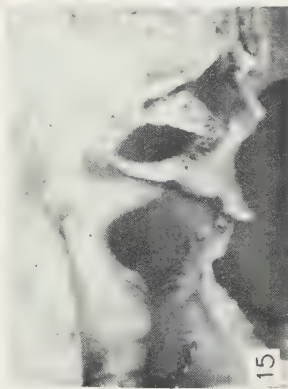


PLATE 3

EXPLANATION OF FIGURES

Variations in the development of the post-glenoid tubercle of adult female apes. Small, intermediate and well-developed examples of each type are illustrated.

20, 21, 22 Chimpanzee.

23, 24, 25 Gorilla.

26, 27, 28 Orang-utan.

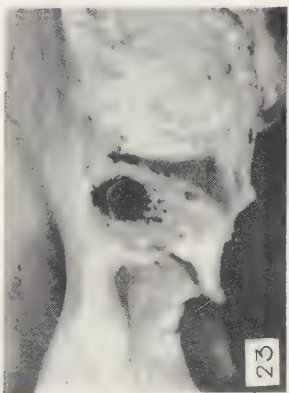
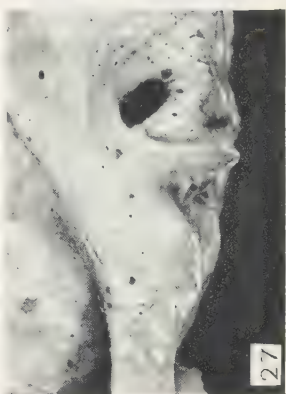
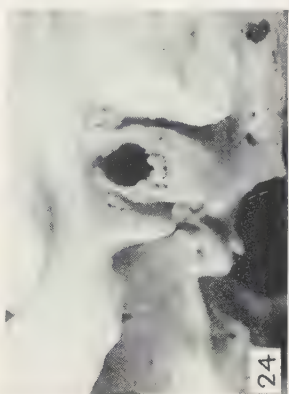
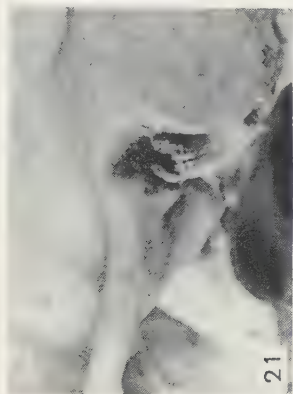
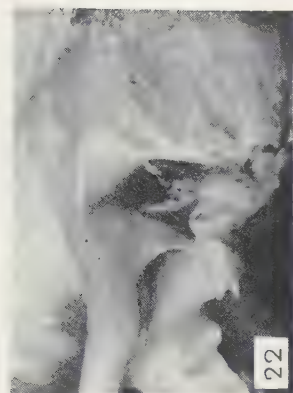


PLATE 4

EXPLANATION OF FIGURES

Variations in the development of the post-glenoid tubercle of adult male apes. Small, intermediate and well-developed examples of each are illustrated.

29, 30, 31 Chimpanzee.

32, 33, 34 Gorilla.

35, 36, 37 Orang-utan.

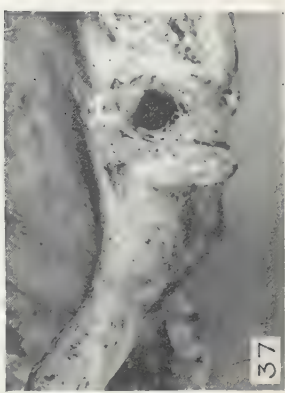
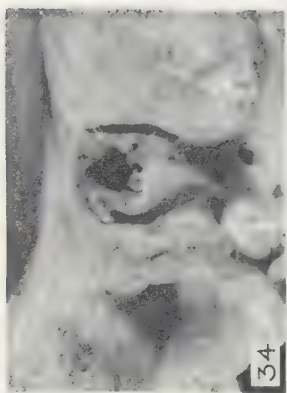
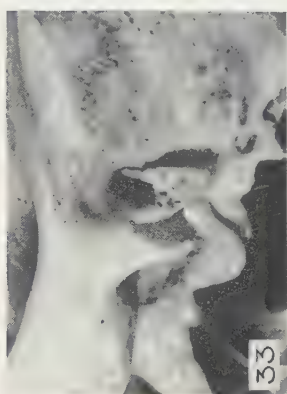
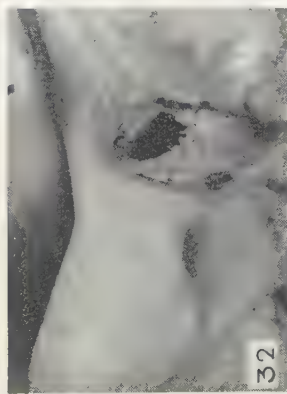
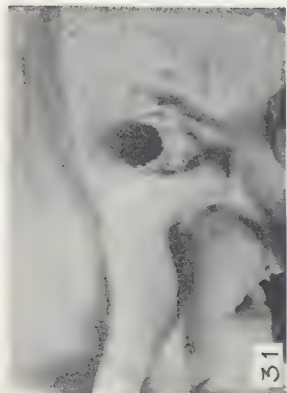
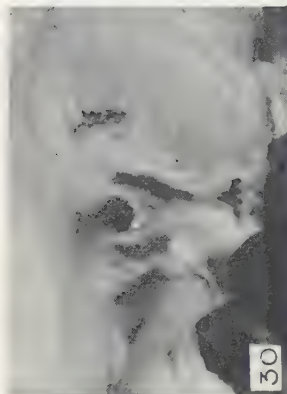
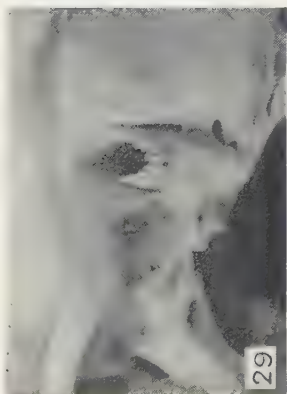


PLATE 5

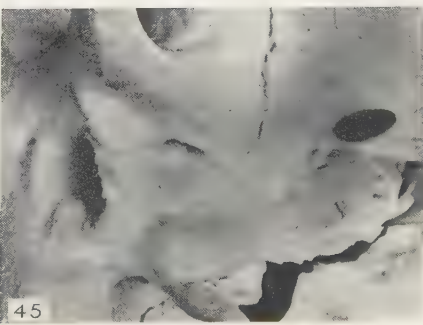
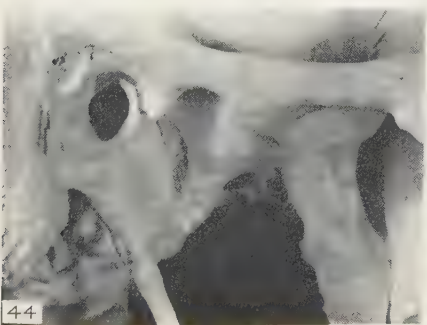
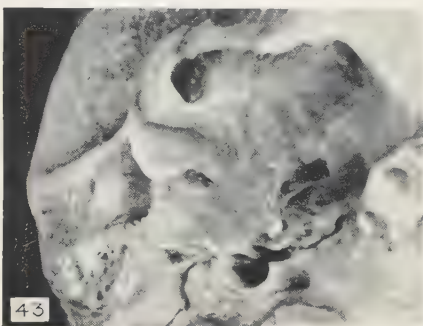
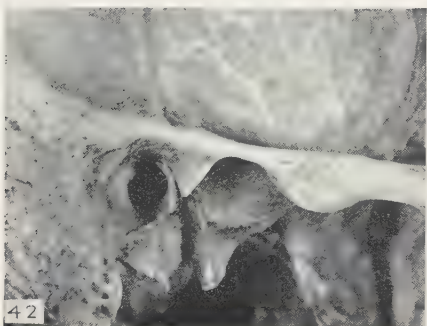
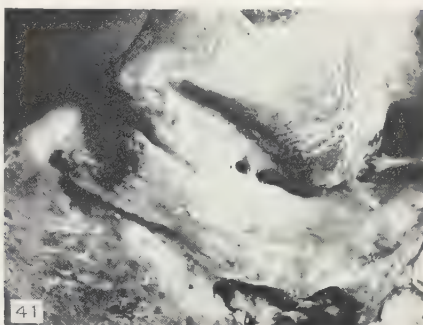
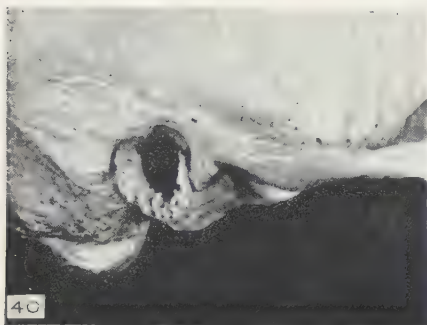
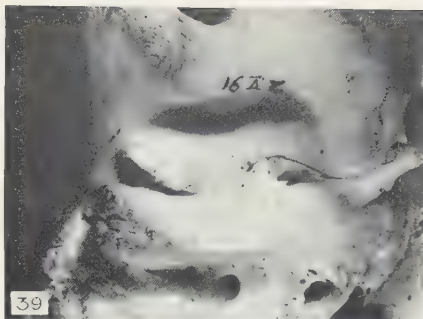
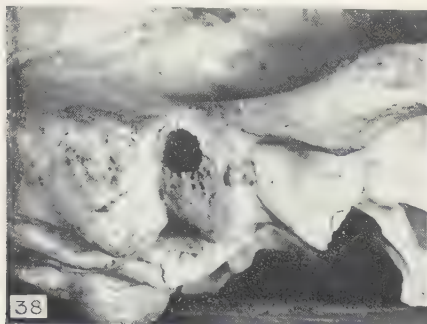
EXPLANATION OF FIGURES

Extreme variation in the development of the post-glenoid tubercle of the gorilla, chimpanzee and man.

38, 39 Adult female gorilla with a small post-glenoid tubercle in relation to the tympanic bone and with a well-developed articular eminence.

40, 41 Adult female chimpanzee, same as figures 38 and 39.

42, 43, 44, 45 Adult man with relatively well-developed post-glenoid tubercles.





CHROMOSOME NUMBER IN THE PRIMATES. — Among the orders of mammals, the primates are almost the least explored in their chromosome history. At the present moment the chromosome number is known only for one or two species of monkeys apart from ourselves: and those observations, although no doubt accurate, were made nearly 30 years ago. Where cytologists abound it seems that monkeys are scarce. Moreover, the owners of collections of living animals maintained for exhibition to the public, or for scientific purposes, are not disposed to lend their precious charges for investigation; or, at least, not until the animals are dead and their chromosomes no longer decipherable. It might well happen therefore that, after the last gorillas, chimpanzees and orang-utans had all expired in their cages, we still should not know their chromosome numbers. We should not know whether, for example, one or more of them had had half or twice our own outfit of chromosomes. Or whether we had differed only by a small amount of fragmentation and the loss or gain of a few inconvenient genes.

Great institutions have been devoted to collecting and preserving, describing and naming, the bony fragments of our ancestors and relatives, and great bodies of literature have been brought forth by their labors. Rightly so. Yet at the cost of a few hundred cells, a few drops of blood, a few moments of discomfort to the animals, and a few hours of work to a cytologist, the genetic record of human evolution could be laid bare. It would, perhaps, be worth while.— C. D. DARLINGTON. Polyploidy in animals. *Nature*, vol. 171, no. 4344, Jan. 31, 1953, pp. 191–194.

THE APPEARANCE OF OSSIFICATION CENTERS AND THE FUSION OF BONES¹

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The maturing skeleton is an index for assessing the developmental status of the growing organism (Greulich and Pyle, '50). Among the skeletal criteria utilized in this connection are the times of appearance of ossification centers and times of fusion of bones. The voluminous literature — citing and presenting data on this subject — gives the definite impression that a wealth of accurate information exists. This conclusion is deceptive for, in fact, original data that are critically documented and accurately defined are scant. The times of appearance of the more than 250 bones differentiating during the first 5 months of human prenatal life may be taken as an example. Only 4 papers present data obtained by direct observations of more than a few centers in many specimens (Mall, '06; Augier, '31; Tiessandier, '44; Noback and Robertson, '51). These 4 papers are based on cross sectional studies of cleared embryos and fetuses — a method of obtaining reliable data. Roentgenographic studies of living embryos and fetuses are of limited value since actual appearance of the delicate fetal centers precedes their roentgenographic recognition and the nature of the projected image complicates the precise identification of many centers of the skull. Three of these 4 papers (Mall, '06; Tiessandier, '44; Noback and Robertson, '51) present their raw data so that they can be pooled — that is the length (age) of each specimen and the bones ossified in each fetus are recorded.

¹ Presented at the 1953 Wenner-Gren Summer Seminar in Physical Anthropology held at the Forsyth Dental Infirmary for Children, Boston, Massachusetts.

Augier ('31) failed to publish his raw data. Of the 590 embryos and fetuses examined by all the above authors only 286 specimens can be used in a critical statistical analysis. Since any one specimen yields data on the appearance of not more than a few centers, 286 embryos and fetuses are a small quantity to do a statistical study of the time of appearance of 250 centers. A few papers present some supplementary data on the appearance of some bones. This illustrates how, when critically analyzed, a seemingly abundant literature boils down to a few substantial papers.

The purpose of this discussion is to note two aspects of the maturation of the human skeleton: (1) to sketch the broad outlines of the periods when ossification centers appear and bones fuse and (2) to note some areas where data are needed.

Statistical data on the times of appearance and times of fusion of bones have many uses. They would (1) improve our information on the physical anthropology of man, (2) would be of use in the problems of assessing maturity and of characterizing somatotypes, (3) would provide a tool for comparative studies on peoples of different ethnic backgrounds and of various medical histories and (4) would be valuable for medico-legal purposes.

THE APPEARANCE OF OSSIFICATION CENTERS

In man, ossification centers appear from the middle of the 6th week after fertilization (clavicle and mandible) until 20 years of age (distal clavicular epiphysis, Todd and D'Errico, '28). Most primary centers differentiate prior to birth while most secondary or epiphyseal centers appear after birth. The latter centers that appear in the late stages of pregnancy have been utilized to establish the degree of prematurity of the newborn infant (Adair and Scammon, '21; Menees and Holly, '32).

The bones may be considered as appearing in three waves: (1) during the first half of prenatal life — most skull bones and diaphyses of the post cranial bones; (2) during late fetal

life until 8 years of age — most epiphyses of the extremities and centers of the carpal bones, tarsal bones and some other bones; (3) during and just following puberty — epiphyses of ribs, vertebral column, pectoral girdle and pelvic girdle.

Figures as to the “general” times of appearance of ossification centers are found in many references. These statements which give no idea as to mean times of appearance have been copied and recopied from sources that are vague guesses or are based upon poor evidence. Except for the work of Sawtell ('29), Pyle and Sontag ('43) and Elgenmark ('48) few data have been analyzed statistically. These authors and Flecker ('42) present a good account of the flaws in many researches. Many investigators do not describe their population samples or the number of individuals examined. Many record age ranges without indicating how they are determined. The times of appearance are then recorded at the time of observation whereas the centers may have appeared months previously. For example, in roentgenograms of a child taken at 6-month intervals a center is recorded as appearing when first observed on the x-ray film even though the center may have differentiated during the prior 6 months. Longitudinal studies in which roentgenograms were taken at short intervals over an extended period are scarce. (The radiological method is an accurate way of observing the development of the living skeleton.) Yet “although the use of roentgenographical examination has been practiced throughout the world for over 44 years, it is a remarkable fact, that despite the millions of exposures which have been made on subjects of all ages and in all regions of the body, no really comprehensive survey of osseous development has ever been attempted” (Flecker, '42). Although the papers noted above and several others have yielded some data to close the gap, Flecker's statement still applies.

The significant studies on the time centers appear during the first half of prenatal life (first wave) are noted above.

Information on the times of appearance of many centers differentiating during the late fetal and the first 8 years

(second wave) can be obtained from statistical studies (Sawtell, '29; Pyle and Sontag, '43; Elgenmark, '46). The atlases on the skeleton of the hand and wrist (Todd, '37; Greulich and Pyle, '50) are valuable for assessing the growth of children.

Good statistical data are not available on the times of appearance of the centers differentiating during the second decade (third wave). Longitudinal studies during this period of puberty and adolescence would be significant. However, a complete analysis of the times of appearance of all the centers is easier to contemplate than to accomplish for many of the centers of the vertebral column and ribs are difficult to demonstrate radiologically. However, the epiphyses of the girdles can be observed and statistical analyses of their times of appearance should be of value.

FUSION OR UNION OF BONES

Most unions of bones occur during the second and third decades of life. These include the fusions of most bones of the postcranial skeleton and some of the cranial bones. In addition some bones fuse during prenatal life and the first decade.

The order of epiphyseal union has been outlined in the literature — especially the fusions of the bones of the extremities (Stevenson, '24; Todd, '30; Stewart, '34) and of the cranium (Todd and Lyons, '24, '25a, '25b, '25c; Cobb, '52). Todd's ('30) comment on the accuracy of data on fusion time is timely: "Observations have been copied from one account to another with slight alterations based upon evidence of no real worth."

Two problems await solution. (1) The interval that it takes for the obliteration of the epiphyseal line is not known — that is from the time fusion is first observed until bony union is completed. Some confusion exists. Stevenson ('24) and others divide the fusing process into several stages while Flecker ('42) concludes this is superfluous because the interval is too short. The latter supports his view by an

x-ray observation of an ulnar epiphysis that was not united on December 16 and was completely fused to its diaphysis on May 29. Serial radiological studies at short intervals could yield valuable data on the length of fusion process. (2) Data are needed to establish the "normal" times of union of fusing bones. Since variability is a characteristic of puberty and adolescence — the time when many bones are uniting — it would be of interest to have data on the times of fusion of bones and degree of variability of the various unions. Longitudinal studies would be more fruitful than cross sectional studies. The technical difficulties of obtaining roentgenograms of the vertebral column and ribs are apparent. However, a serial study limited to the fusion of a few bones would prove significant.

The problem of suture closure of the cranial bones is presented by Cobb ('52) and Singer ('53). The latter author concludes "that the assessment regarding the precise age at death of an individual, gauged only on the degree of closure of the vault sutures of the skull, is a hazardous and unreliable procedure." Possibly Cobb's unpublished study may yield definitive quantitative data on this subject.

SUMMARY AND CONCLUSIONS

1. The status of the problem of the times of appearance and times of fusion of bones is presented.

2. The maturing skeleton has been utilized in a number of anthropological, medical and biological problems. It could be used to better advantage if more statistical data were available on the times of appearance of ossification centers and the times of fusion of bones.

Such statistical data (a) would give more information on the physical anthropology of man, (b) could be utilized in the problems of assessing maturity and characterizing somatypes, (c) would provide a tool for comparative studies on peoples of different ethnic background and of various medical histories and (d) would be valuable for medico-legal purposes.

3. The data on the times of appearance of the primary ossification centers (most appear in first half of prenatal life) are insufficient to give more than a general outline of the times that these bones appear.

4. Some statistical data on the times of appearance of the carpal and tarsal bones and the epiphyseal centers of the extremities are recorded (Sawtell, '29; Pyle and Sontag, '43; Elgenmark, '48). Much of the literature is inadequately defined.

5. The epiphyses of the girdles, ribs and vertebral column appear during and following puberty. The fusion of bones is most active during the second and third decades. Statistical analyses of the times of appearance of these bones and the union of any two bones cannot be made at the present time because accurately documented data are too scarce.

Although technical difficulties to obtain information exist, accurate data on a limited number of bones would be valuable.

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EXPERIMENTAL STUDIES IN BODY BUILD.—Though a great deal has been written about the physical growth of the human, and about differences in body build between one person and another, comparable literature on other animals is extraordinarily sparse. This is somewhat surprising, since bodily differences, being largely genetic, are much more readily studied in laboratory stock. It is also unfortunate, in that lack of animal data prevents our knowledge of human growth and physique being placed in its proper biological perspective. This situation will only be remedied when complete longitudinal studies of the growth of animal stocks are undertaken and carried through, but meanwhile some animal material is available, and previous papers of this series have described, in inbred races of rabbits, genetically controlled differences in various morphological traits, chiefly as seen in the newborn. The present paper analyzes the differences between the vertebral bodies of adult animals in three inbred races of rabbits. It reaches the conclusion, by way of analyses of variance, that these are best described in terms of factors for general size, for linearity, and for growth of particular regions, a result strikingly similar to that emerging from the factor-analysis classification of human physique.

Further advances along these lines would seem to lie in constructing quantitative measures for size, shape and regional factors, and breeding selectively for extremes^{*} in each of them. Such studies might ultimately throw considerable light on the genetics of physique in other species, including man, and thus ultimately on numerous problems of human health and welfare. The importance of genetically controlled animal material in this regard can scarcely be over-emphasized.—J. M. TANNER AND P. B. SAWIN. Morphogenetic studies of the rabbit. XI. Genetic differences in the growth of the vertebral column and their relation to growth and development in man. *J. Anat.*, vol. 87, pt. 1, 1953, pp. 54–65.

DIFFERENTIAL GROWTH ANALYSIS OF BONE MORPHOLOGY ¹

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ONE FIGURE

Differential growth technics, introduced about 50 years ago, received biological impetus with the work of Huxley ('32). Since differential growth is related to the concept of self-multiplication of growing tissues, some doubt has been felt concerning the applicability of this technic to bone growth study. The essentially accretionary nature of osteogenesis has been correctly regarded as ruling out an interstitial mode of bone formation. However, if we view bone to be the resultant of the self-multiplicative processes of the surrounding osteogenic tissues, then the differential growth concept is clearly applicable. In this case, we do not measure the growth of the bone itself as much as we measure the relatively permanent record of the self-multiplicative osteogenic tissue growth.

The differential growth equation expresses the relationship between two parameters, x and y , as

$$y = bx^k \quad (1)$$

This exponential function is usually rendered

$$\ln y = \ln b + k \ln x \quad (2)$$

As may be seen, plotting of the logarithms of the two parameters will result in a straight line if k is constant. The numerical value of k may be determined by measurement of the slope of the line produced. When we adopt the short

¹ This paper was first given at the Wenner-Gren Summer Seminar in Physical Anthropology, 1953.

² Post-Doctoral Fellow, National Institutes of Health.

cut of plotting on log-log paper, we make graphic the multiplicative nature of the phenomenon we are studying.

The constant k is the ratio between the specific growth rates of the two parameters, where

$$\frac{dy}{y} dt = \frac{d \ln y}{dt} \quad (3)$$

and

$$\frac{dx}{x} dt = \frac{d \ln x}{dt} \quad (4)$$

This demonstrates an important property of differential growth analysis, the "cancelling out of time." For our purposes, the factor b may be regarded as the y intercept.

What this method of growth analysis omits is as important as what it contains. Needham ('50) has concisely put it that we abstract from morphological form, from factors of nutrition, from absolute values of magnitude, and most important of all, from time. We retain only a relative system of ratios and relations.

While the differential growth equation is admittedly empirical with no objective meaning, insofar as it will not give us any grasp of underlying biological, chemical, or physical forces, it will provide a tool for the study of form which is meaningful within its limitations. The empirical nature of this method is only justified in that it yields a more easily comprehended array of data. The straight lines produced by differential growth, when so analyzed, permit of easier interpretation, insofar as the eye is able to detect variations from a straight line with greater ease than from a curve. In addition, the simpler formulation stands in marked contrast to others which have been utilized.

The relation of the differential growth equation to the sigmoid growth curve is a point of some contention. Lumer ('37) has given an excellent critique, pointing out that the differential growth formulation has as its basic assumption that each parameter exhibits (a) a constantly decreasing self-multiplicative growth rate, (b) a sigmoid type of growth, and (c) a different specific growth rate. However it is evident from Lumer's paper that while the differential growth for-

mulation is, admittedly, only a first approximation, it will nevertheless fit a good portion of the sigmoid curve. It is valid to claim that whatever significance this type of formulation entails, it will fit data drawn from extended portions of the sigmoid growth curve.

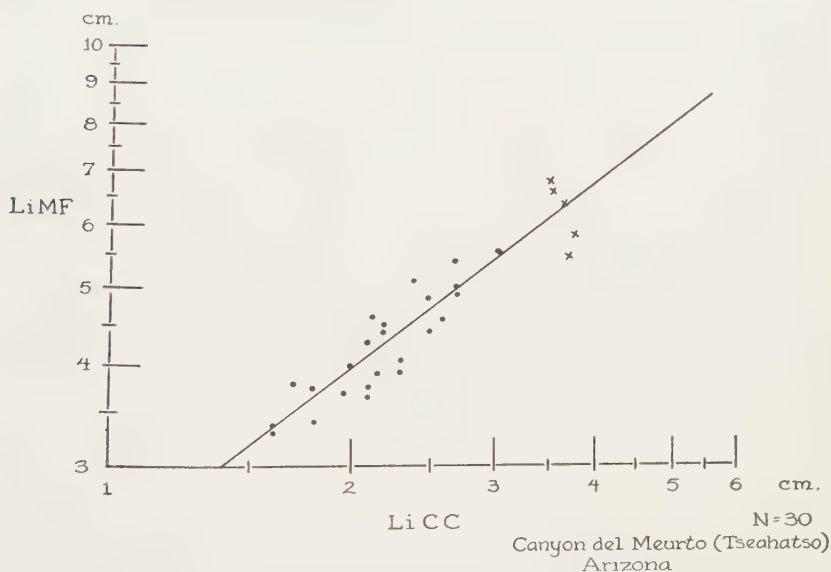


Fig. 1 Relative growth of two dimensions of the human mandible, from the circumnatal stages (.), at the left, through the adult stages (X), at the right.

LiMF: A horizontal measurement extending from the lingula of the mandibular foramen to the anterior border of the mental foramen.

LiCC: A vertical measurement extending from the highest point on the condyle to the lingula of the mandibular foramen.

The application of this technic in the study of the growth of various bones has proved fruitful. A cross sectional analysis of the segments of the human mandible, from circumnatal to adult stages, shows a constant allometric (differential) relationship between the segments (see figure 1). Furthermore, comparison of these segments between adults of various human groups gives evidence that this technic may prove useful in a phylogenetic as well as an ontogenetic sense (Moss, '52). It has already done so for Hersh ('34), in the case of titanotheres.

Similar analytic methods applied to the growth of the various dimensions of the long and calvarial bones of mice (Levy, Rugh, Lunin, Chilton and Moss, '53), rat (Moss, unpublished), and human fetuses (Moss, Noback and Robertson, unpublished), further demonstrate the existence of constant relationships (i.e. a straight line on log-log plots) between the various parameters of each bone and between the bones themselves.

Growth is a subject of perennial biological interest. While the definitions of growth vary extensively, growth is generally denoted as a change in a parameter which is detectable. If, in addition, this change is quantifiable, we may discuss the relations between the various parameters involved in this growth. Alteration in form entails a change in the relative proportions brought about by the differential growth relation between the various chords and dimensions of a single bone, or a complex of bones. The existence of such a relationship, while of intrinsic interest in itself, is not surprising in view of similar growth relations found to exist for the body as a whole (Jaso, '51). The establishment of differential growth patterns at the level of the individual bones serves to carry the concept of a "regressus of patterns" within the organism, as suggested by Hersh ('41), down to the lowest level of gross morphological observation. The data on differential growth at the submicroscopic level is fully presented by Needham ('50).

In summary, differential growth analysis serves as a useful technic for the study of bone growth. Further extension of this method will undoubtedly yield a more complete understanding of the basic problems of morphogenesis.

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HISTORICAL ASPECTS OF ORGANIC EVOLUTION. Philip G. Fothergill. (xv, 427 pp., \$6.00. Philosophical Library, New York, 1953.) — Approximately one-half of this book gives a chronologically arranged historical account of developing evolutionary theory up to 1900. The second half deals with modern theory as a synthesis of many recent investigations. The historical section is thorough and a real contribution to the record. The second part of the book is primarily unusual in view of the favorable discussion given to the doubtful evidence for the inheritance of acquired characteristics. The weight of discussion given to views varying from the more common selection-mutation theory of evolution is at least stimulating.

GROWTH RESPONSES TO DIET CHANGES.—Children and particularly adolescent children are measurably affected in times of stress as the result of environmental changes, including actual food shortage, or as the result of economic stress. They exhibit a retarded rate of increase in height and weight. The increase in weight may even be less than that expected for the particular height attained. The failure to grow at an expected rate may be due to a simple lack of sufficient food, failure to eat, to specific inadequacies of the diet or to a combination of these factors. It is often assumed that the child that fails to grow at the normal rate is seriously affected at the time or in later life, that he is stunted in size and even subject to increased rates of infection. The ultimate effects of retardations in growth in man have not, however, been carefully studied or determined. The increased morbidity that exists during periods of war and following a war is often ascribed to food without taking into consideration the poverty, stress and poor hygienic conditions which are also associated with such periods. . . .

Graphs are presented of the average height and weight of the boys and girls enrolled in schools, both in the Volksschule and Oberschule, at Stuttgart, Germany, from 1915 to 1948. The data cover changes in average stature in the school children over a long period which included two World Wars. In general similar effects of environment are shown—as well as a trend toward a more rapid rate of growth, especially between the years 1914 and 1926. No information is available on adult height or weight or the effect of environment or changes in environment on the ultimate adult height.—PAUL E. HOWE AND MARIA SCHILLER. Growth responses of the school child to changes in diet and environmental factors. *J. Appl. Physiol.*, vol. 5, no. 2, Aug., 1952, pp. 51–61.

MAN, TIME AND FOSSILS. Ruth Moore. (411 pp., 32 plates, 71 drawings, selected bibliography and index. \$5.75. Alfred A. Knopf, New York, 1953.)—Well written, illustrated and organized, this attractive book uses the biographic method to tell who did what in developing the story of human evolution. Darwin, Lamarek, Giard, Cope, De Vries, Mendel, Haldane, Fisher and Wright are seen as builders of evolutionary theory. Other investigators related to the development of the fossil record and the thought strictly concerned with the human phases of evolution complete the coverage. While not written for the professional student of human evolution this book gives a good up-to-date account of this fascinating field to the general reader.

BIOMETRICS OF CROWDING AND SPACING OF THE TEETH IN THE MANDIBLE¹

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FOUR FIGURES

The alignment of the teeth in the dental arch is in any final analysis partially dependent on the ratio between the size of the teeth and the size of the dental arch. A perfect alignment of the teeth is possible only when an optimum relationship between these two factors exists. A disproportion between the size of the arch and that of the teeth it contains results in either crowding or spacing of the teeth.

In the present study a biometric analysis is made of spacing or crowding of the teeth in the mandible. The study was confined to the mandibular dentition because it was reasoned that in the mandible the teeth, especially the incisors, are generally positioned directly over the basal arch, whereas in the maxilla this is not as often the case. The long axes of the maxillary incisors may have a considerable inclination to the occlusal plane and, therefore, the maxillary dental arch may have a larger circumference than the bony basal arch. Since the size of the *dental* arch — the arch formed by the crowns of the teeth — is likely to correspond more closely to the *basal* arch in the mandible than in the maxilla, it seemed to the writers that the above discussed relationship can, when only casts are used, be evaluated more effectively by studying the mandibular dentition.

¹ Presented in part at the 21st Annual Meeting of the American Association of Physical Anthropologists, March 21, 1952.

The material available for analysis consisted of 72 plaster casts of the mandibular dentition of 18- to 20-year-old American females of European stock, with a full complement of permanent teeth (M_2 to M_2). None of these subjects had received orthodontic treatment. The plaster casts were obtained from "hydrocolloid" impressions,² since this method

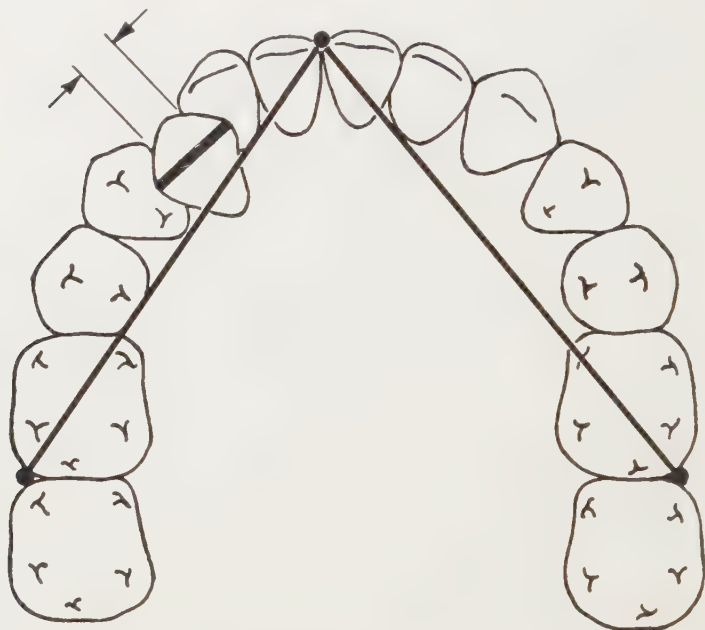


Fig. 1 The distances from infradentale to the distal surfaces of the mandibular left first molar and its antimere, utilized to obtain an approximate measure of the size of the dental arch, together with an illustration of the manner in which the degree of crowding of one tooth was determined.

provides an accurate anatomical representation of the dentition (Warrer, '52).

On the plaster casts measurements were made of mesiodistal crown diameters of the teeth, the amount of spacing or crowding and the size of the dental arch.

Mesiodistal crown diameter was obtained by measuring the greatest distance between the approximal surfaces of a tooth.

² Coe-loid impression material.

The crown dimensions of individual teeth have been added to obtain a metric value for the total tooth material exclusive of the second and third molars.

Spacing was measured by placing wires of different, but known, gauges in an interdental space until a wire was found which corresponded in thickness, within 0.1 mm, to the width of the space at the level where approximal contact usually occurs.

Crowding was measured as the lack of space for a tooth in the dental arch (fig. 1). This metric expression for the degree of crowding was derived by subtracting the amount of space available for a crowded tooth in the dental arch from the mesiodistal crown diameter of the former (Seipel, '46).

The size of a dental arch was expressed in terms of the length of the curve extending from the distal surface of the left mandibular first molar to the distal surface of its anti-mere, measured along the midline of the row of teeth between these points. Two different methods for determining this linear dimension were utilized, namely:

- (a) Sum of mesiodistal crown diameters (M_1 to M_1)
— crowding.

Or, in the case of spacing of the teeth:

- (b) Sum of mesiodistal crown diameters (M_1 to M_1)
+ spacing.

According to this method the size of the dental arch was obtained indirectly by utilizing the measurements for the individual teeth and those for spacing or crowding.

Another expression for the size of the dental arch was obtained by measuring the distances between infradentale and the distal surfaces of the mandibular first molars (fig. 1). These two dimensions, which are functions of the length and breadth of each half of the dental arch, when added together only approximate the true size of the dental arch, because they do not take its curved contour into consideration. This measure for arch size is, however, totally independent from

that obtained indirectly by considering the diameters of the tooth crowns and the measures for crowding and spacing.

The results obtained by these two methods were compared by calculating the coefficient of correlation. This coefficient

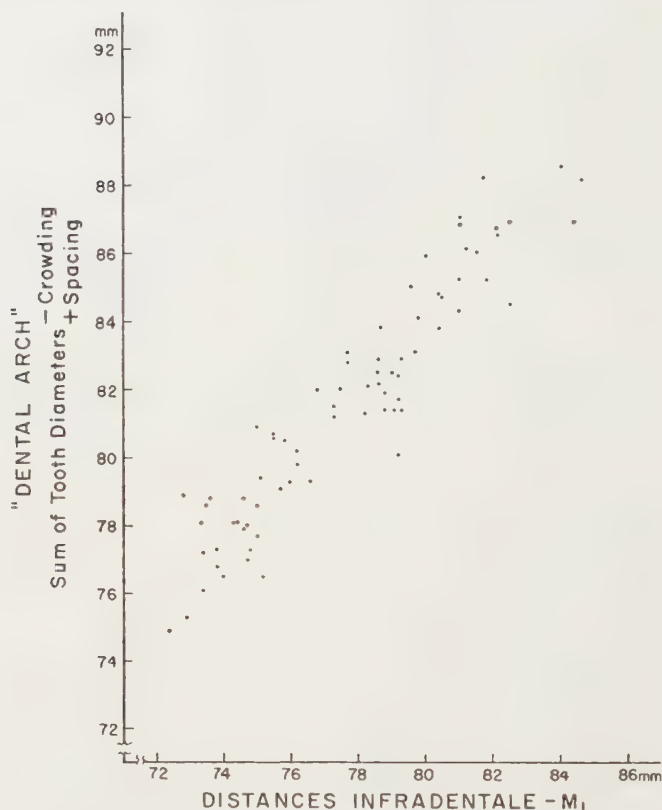


Fig. 2 A scattergram to demonstrate the degree of association between the two methods used for measuring the size of the dental arch. $r = +0.97 \pm 0.007$, $n = 72$.

was quite high, i.e., $+0.97 \pm 0.007$ ($n = 72$) (fig. 2). It is of sufficient magnitude to permit the use of the first method of measurement, which is considered to give a more accurate approximation of the actual length of the curved line that characterizes the dental arch of man.

Lundström ('42), who likewise attempted to find a satisfactory method for measuring dental arches, described three different methods for making this determination, namely:

- (1) By determining the length of a thread which had been carefully laid along the vestibular surfaces of the row of teeth.
- (2) By combining measures of arch breadth and length.
- (3) By adding sectional measurements, each of two neighboring teeth.

TABLE 1

*The errors of measurements made independently by two investigators*¹

MEASUREMENT	σ_{error}	N
Mesiodistal crown diameters of individual teeth	0.09 mm	360
Crowding of single teeth	0.20 mm	79
Combined mesiodistal crown diameters (M_1 to M_4)	0.43 mm	30
Total crowding on one cast	0.33 mm	30
Size of the dental arch (= Σ crown diameters — crowding)	0.55 mm	30
Distance infradentale to M_1	0.10 mm	60

¹ Computed from the formula: $\sigma_{\text{error}} = \sqrt{\frac{\Sigma \text{differences}^2}{2n}}$.

After comparing the results obtained by utilizing these methods, Lundström found the first method the most suitable for the purpose. No attempt was made to employ this method because it was not found particularly suitable for measuring arches with markedly crowded teeth.

All measurements in the present study were made with a sliding caliper equipped with a vernier scale which made it possible to obtain readings of 0.1 mm. The errors of measurements by different investigators were calculated from a small number of double determinations utilizing the formula:

$\sigma_{\text{error}} = \sqrt{\frac{\Sigma \text{differences}^2}{2n}}$ (table 1). To obtain a greater degree of accuracy, all measurements were repeated at least twice by different observers. This proved to be especially

advantageous in arriving at a reasonably correct expression for the amount of crowding.

The aim of this study, as stated previously, is to examine the sources of variations in the alignment of the teeth *in casu* spacing and crowding of the mandibular teeth of the individuals furnishing the data. In statistical terms it can be said that an attempt is made to understand the composition of the variance between individuals in the crowding and spacing of the teeth (σ_{CS}^2).

Spacing and crowding actually signify opposite ends of a scale which characterizes variations from perfect tooth alignment in the horizontal plane. Instead of these terms, plus and minus signs can be used to express a surplus of space for the teeth (spacing) or a lack of space (crowding).

The biometric method developed for an understanding of the variance of crowding and spacing is based on the fact that:

Crowding = (sum of mesiodistal crown diameters) — (size of dental arch)

Spacing = (size of dental arch) — (sum of mesiodistal crown diameters)

From this relationship it follows directly that the variance of individuals along this crowding-spacing scale may be written:

$$\sigma_{CS}^2 = \sigma_T^2 + \sigma_A^2 - 2r_{TA}\sigma_T\sigma_A \quad (1)$$

Thus, the amount of variability observed in crowding or spacing of the teeth may be expressed as a function of three quantities:

1. σ_T^2 The variance of the combined mesiodistal crown diameters (M_1 to M_1).
2. σ_A^2 The variance of the size of the dental arch occupied by these teeth (M_1 to M_1).
3. r_{TA} The correlation coefficient between the combined size of the tooth crowns and the size of the dental arch.

It is, however, more useful to alter the form in which this relationship is expressed, in the following manner:

$$\begin{aligned} \sigma_{CS}^2 &= \sigma_T^2 + \sigma_A^2 - 2r_{TA}\sigma_T\sigma_A \\ &= \sigma_T^2 - 2\sigma_T\sigma_A + \sigma_A^2 + 2\sigma_T\sigma_A - 2r_{TA}\sigma_T\sigma_A \\ &= (\sigma_T - \sigma_A)^2 + 2\sigma_T\sigma_A(1 - r_{TA}) \\ &= \sigma_T\sigma_A \left[\frac{(\sigma_T - \sigma_A)^2}{\sigma_T\sigma_A} + 2(1 - r_{TA}) \right] \end{aligned} \quad (2)$$

In this revised form the variability in tooth position is again expressed in terms of three quantities, but these quantities are more susceptible to interpretation:

1. $\sigma_T \sigma_A$ A combined measure of the variation in the size of tooth crowns and dental arches. This factor expresses the fact that dentitions with great variability in tooth and dental arch size may be expected to show great variability in crowding or spacing of the teeth. It contains all the information with regard to absolute dimensions.
2. $\frac{(\sigma_T - \sigma_A)^2}{\sigma_T \sigma_A}$ A non-dimensional measure of the amount of discrepancy between the range of variation of the size of the teeth and that of the dental arches. This factor expresses the fact that if teeth are more or less variable than dental arches, some variation from a perfect tooth alignment may occur.
3. $(1 - r_{TA})$ A non-dimensional measure of the lack of association between the size of the teeth and of the dental arch in individuals. This factor expresses the fact that failure to have tooth size proportional to arch size will lead to crowding or spacing of the teeth.

It will be noted that the variance of crowding and spacing of the teeth, as measured by σ_{CS}^2 , will be zero only when both quantities in the square brackets of the formula (2) are zero, i.e.,

$$\begin{aligned} \sigma_{CS}^2 &= 0 \\ \text{only when } \frac{(\sigma_T - \sigma_A)^2}{\sigma_T \sigma_A} &= 0 \quad \text{or} \quad \sigma_T = \sigma_A \\ \text{and } (1 - r_{TA}) &= 0 \quad \text{or} \quad r_{TA} = 1 \end{aligned}$$

These two quantities can be visualized as representing two different sources of variability from a perfect tooth alignment.

A graphic illustration of the thesis developed is given in figure 3. In figure 3 A a complete absence of variance of crowding or spacing is sketched, ($\sigma_{CS}^2 = 0$). The distribution curve of the size of the combined crown diameters of the teeth and that of the size of the dental arches are identical ($\sigma_T^2 = \sigma_A^2$). In addition, there is a complete absence of scatter around the regression line which indicates perfect association between the size of the teeth and of dental arches ($r_{TA} = 1$).

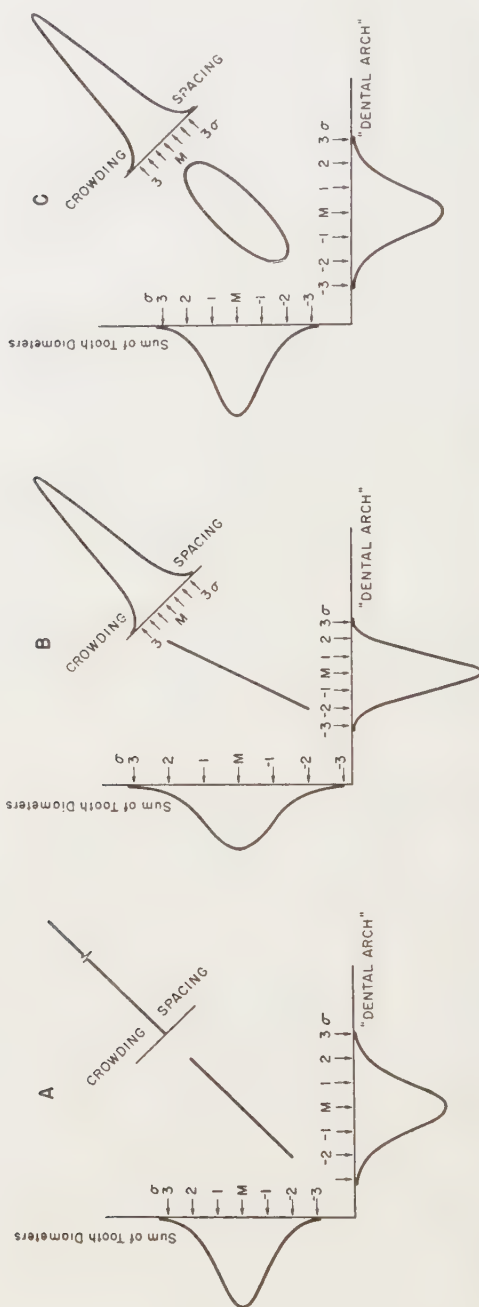


Fig. 3 An illustration of the thesis developed for the analysis of variance of spacing and crowding of the teeth. These three figures are based on mathematical computations.

- A. No crowding and spacing of the teeth: $\sigma_v^2 = \sigma_A^2$; $r_{TA} = 1$
 B. Crowding and spacing of the teeth: $\sigma_v^2 > \sigma_A^2$; $r_{TA} = 1$
 C. Crowding and spacing of the teeth: $\sigma_v^2 = \sigma_A^2$; $r_{TA} < 1$

When, however (fig. 3 B), the variance of the combined size of the teeth becomes larger than that of arch size ($\sigma_T^2 > \sigma_A^2$), the variance of crowding and spacing is no longer zero ($\sigma_{CS}^2 > 0$), even when a perfect association exists between the size of the tooth crowns and dental arches, with and absence of scatter around the regression line ($r_{TA} = 1$).

Likewise, variance of spacing and crowding occurs ($\sigma_{CS}^2 > 0$) when the association between the size of the tooth crowns and the dental arches is imperfect (fig. 3 C), with marked scatter around the regression line ($r_{TA} < 1$), regardless of the similarity in the variance of tooth size and arch size ($\sigma_T^2 = \sigma_A^2$).

The two sources of variance in spacing and crowding can be expressed as proportions, namely:

$$\frac{(\sigma_T - \sigma_A)^2}{\sigma_T \sigma_A} = \frac{\left[\frac{(\sigma_T - \sigma_A)^2}{\sigma_T \sigma_A} + 2(1 - r_{TA}) \right]}{2(1 - r_{TA})} =$$

The proportion of variance of crowding and spacing due to a discrepancy between the variances of teeth and dental arch.

$$\frac{2(1 - r_{TA})}{\left[\frac{(\sigma_T - \sigma_A)^2}{\sigma_T \sigma_A} + 2(1 - r_{TA}) \right]} =$$

The proportion of variance of crowding and spacing due to a lack of correlation between teeth and dental arch.

Substituting actual findings (table 2) in the formulas derived, showed that the variance of crowding and spacing was only in a small percentage (0.7%) due to a discrepancy between the variances of tooth material and dental arches. The variance of crowding and spacing is in a very much greater

TABLE 2

The data used for the analysis of crowding and spacing of the teeth

(N = 72)

	MEAN	σ
Combined mesiodistal crown diameters		
of the mandibular teeth (M_1 to M_4)	82.83 mm	3.59 mm
Size of the mandibular dental arch	81.56 mm	3.46 mm
Crowding (—) and spacing (+) of the teeth	—1.27 mm	1.64 mm

The coefficient of correlation between size of teeth and size of dental arch
 $= 0.90 \pm 0.022$.

percentage (99.3%) due to a lack of association between the size of the teeth and the size of the dental arch. Thus, it appears that for the group studied the findings coincide, for practical purposes, with the situation sketched in figure 3 C. Inspection of figure 4, in which the findings of the present study are depicted, shows that crowding may occur in individuals with less than average tooth size and also in individuals with more than average arch size.

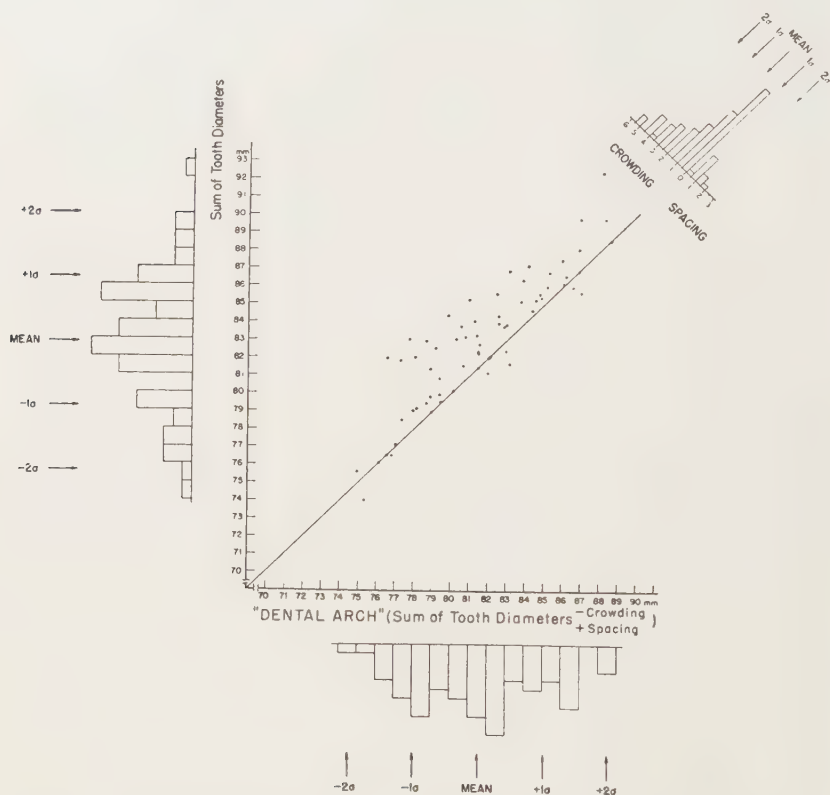


Fig. 4 A graphic depiction of the biometric analysis of crowding and spacing in the mandibular dentitions of 72 females. Note: Dots above the diagonal line represent dentitions with crowding, those below the line dentitions with spacing. Dots on the diagonal line indicate a perfect harmony between tooth size and arch size.

These findings are of interest in relation to earlier studies of the relationship between tooth size and crowding. Lundström ('42) found a negative correlation coefficient between the sum of tooth breadths (Pm_1 , C , I_2 , and I_1) and an expression of the degree of crowding of the teeth (Pm_1 to Pm_1) in 13-year-old Swedish boys and girls: $r = -0.49 \pm 0.08$ in the maxilla and -0.39 ± 0.07 in the mandible. On the basis of these data he concluded that crowding is more common in dentitions with large than with small teeth.

According to Seipel ('46) the coefficient of correlation between crowding of the teeth and mesiodistal crown diameters from I_1 to P_2 , in 21-year-old Swedish females, was -0.38 ± 0.12 for the mandibular dentitions. This investigator also studied the relationship between "jaw size" and crowding or spacing of the teeth, but only in the maxilla.

In our material the coefficient of correlation between the sum of mesiodistal crown diameters (M_1 to M_1) and crowding or spacing of the teeth was -0.34 ± 0.10 , which approximates the findings of Lundström and Seipel for the mandible. The coefficient of correlation between crowding or spacing of the teeth and the combined distances from infradentale to the distal surfaces of left and right mandibular first molars was $+0.17 \pm 0.11$.

It is difficult to evaluate the various factors leading to crowding or spacing of the teeth by merely correlating the size of the tooth crowns or the size of the dental arch with the amount of crowding or spacing, since both conditions are the joint product of the size of the teeth and the size of the dental arch.

The method used in the present study leads to a clearer evaluation of the role which tooth size and arch size play in the causation of spacing and crowding. In fact, it has been shown that a discrepancy between the variances of tooth size and arch size plays practically no part and that actually a lack of association between tooth size and arch size leads to crowding and spacing in the mandibular dentitions of the 72 females studied. This conclusion should be accepted within

the limitations imposed by the method of analysis and the source of the data.

ACKNOWLEDGMENTS

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AGE CHANGES IN HEAD HAIR FROM BIRTH TO MATURITY

IV. REFRACTIVE INDICES AND BIREFRINGENCE OF THE CUTICLE OF HAIR OF CHILDREN ¹

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FOUR FIGURES

The polarizing microscope and refractometer have been employed for more than a century in examining the ultra-structure of textiles and of certain cytological and histological materials. Summaries of the findings may be found in reports by Schmidt ('24, '37, '39), Rinne and Berek ('34), Frey-Wyssling ('38), and Schmitt ('39).

Studies of refractive index and birefringence of human hair under the polarizing microscope have been somewhat limited. Von Ebner in 1882 examined hair under the polarizing microscope and concluded that double refraction or birefringence of both hair and fingernails is due to the tension under which the tissue is placed during growth. He noted that the long axis of a hair corresponds to its optical axis and that a hair appears to be quite light when the nicols of the polarizing microscope are perpendicular, and reaches maximum darkness when the nicols are parallel. He observed marked birefringence in flattened or irregular hair. Root sheaths exhibited positive double refraction while birefringence was noted to vary in a cross section of hair, the double refraction being stronger for the horny layers and

¹ This investigation was supported (in part) by a research grant to Dr. Mildred Trotter from the Wenner-Gren Foundation for Anthropological Research, Inc.

² In partial fulfillment of the requirements for the degree of Doctor of Philosophy.

weaker for the deeper layers. Under the polarizing microscope variations in interference colors were noted when additional weight or strain was placed on the hair.

More recently, in Kirk's laboratory at the University of California (Greenwell, Willmer and Kirk, '41), 2,529 hairs from the crown region of 97 individuals of various ages and racial backgrounds were examined. A single index of refraction of the cuticle of the hair of each sample was measured using calibrated oils and oblique and normal white light illumination. The Becke line was used for interpreting the index. It was concluded that refractive index has a definite though limited value in individualizing human head hair since variation among hairs of a given individual is definitely less than that among individuals of a given race. They further suggested that refractive index appears to be one of the best criteria yet discovered for the determination of sex from hair of adults. This suggestion was based on the distribution curves of the Caucasian subjects in which there was no overlap of refraction indices between the sexes in 80% of the cases. However, the hair of boys under the age of puberty exhibited a refractive index similar to that of girls.

The hair of the non-Caucasian subjects averaged a higher index of refraction than did the hair of the Caucasians. All hairs from the same individual exhibited a uniform maximum spread of refractive indices of approximately 0.002. Thus, if the values of two hairs differ as much as 0.004 it was believed that they could not have come from the same individual. A marked divergence in refractive index was noted for hair with "permanent waves."

Greenwell, Willmer and Kirk also made limited observations on refractive index with reference to age and family relationships. No significant similarities were noted among related subjects. However, in five instances hair from the same individual was available at two or three different ages. Of these, with one exception, the refractive index showed a decrease with increase in age and the decrease was roughly proportional to the increase in age. This finding suggested

that the differences in index may have been caused by dehydration, oxidation or other chemical alteration during storage, in other words, that storage of hair may produce an increase in its refractive index.

Garn ('51) also used the polarizing microscope for examining the structure of human hair. He pointed out that the crystallites of keratin in the hair shaft possess an orderly arrangement similar to that in certain textile fibers with at least one axis parallel to the long axis of the hair. Since birefringence increases with increasing degrees of keratinization (the cortical cells are more birefringent than the medullary cells, the cuticle more birefringent than the cortical cells and the flattened cells near the neck of the follicle are more birefringent than the cells nearest the center of proliferation), he suggested that a study of these differences should contribute to an understanding of the structure of hair.

Candela (personal communication) has studied the significance of the colors obtained in the extinction phase when hair is placed between two prisms. He noted that the color patterns produced differ radically, not only of hair from different individuals, but even among hairs from the same individual. He postulated that these differences may be due to the size and shape of the hair or associated with structural discontinuities.

It is the purpose of this investigation to present the results of a longitudinal study of refractive indices of the cuticle of children's hair with special emphasis on age and sex differences as well as on variations between individuals and finally between hairs of the same individual.

MATERIAL AND METHOD

The hair samples are from the same group, 9 girls and 7 boys, on which studies of index, cross-sectional area, percentage incidence of medullation and cuticular scale counts have been reported (Trotter and Duggins, '48; Duggins and Trotter, '50; Trotter and Duggins, '50). Briefly, they are 16 white children, of which 5 pairs are siblings including one pair of

identical twins and two pairs of first cousins. They were born between 1930 and 1942. Monthly samples from the vertex beginning at birth are on file; however, only the birth sample and every 12-month sample thereafter were examined for refractive index.

The method employed in this study for determining the refractive index and birefringence of hair is a modification of the simple Becke method and has been described in the literature as the double-variation method (Gibb, '42). The double-variation procedure is capable of greater accuracy than the Becke method and develops additional information.³ The distinguishing features are a monochromatic source of illumination together with the use of comparatively few immersion media, whose refractive indices may be varied by changing their temperatures.

The apparatus consists of an Abbe refractometer, a polarizing microscope, a constant temperature circulating water bath, a specially constructed temperature cell, a monochromator of high intensity (sodium 5,893 Å) and a series of certified oils of refraction. The constant temperature bath circulates a stream of water at a desired temperature through the hollow prism casing located on the stage of the polarizing microscope. The source of illumination for both the microscope and refractometer is the monochromator.

A section of hair 4–8 mm in length was taken from the proximal end of each of five unselected hairs from a given sample. The birth sample and each yearly sample thereafter were examined. After agitation for 15 minutes in a solution of ether and 95% alcohol the five sections of hair were mounted on the temperature cell in a medium of known index. A few drops of the same liquid were placed in the refractometer. For accurate readings it is necessary that the hairs be oriented properly on the stage of the polarizing microscope. The long axis of the hair must be either parallel or perpen-

³ Special Agents Richard Flack and Roy Jevons of the F.B.I. Laboratory, Washington, D.C. provided technical assistance in adapting the double-variation method to the examination of hairs.

dicular to the prisms of the substage polarizer. The reading at 0° will be referred to as the 0° or parallel reading and the reading at 90° will be the 90° or perpendicular reading. The difference between the parallel and perpendicular readings is the birefringence. Readings were made directly to three decimal places and estimated to the fourth place. Accuracy of the procedure was maintained by supplementing the Becke line with the half-shadow technique. This method is theoretically accurate to .0005 but in actual practice was found to be accurate to .001 of an index point.

Determination of refractive indices for each of fifteen hairs from each yearly sample were made for subject A. A study of these measurements indicated that although there were minor variations among the refractive indices of different hairs at any given age, the averages of the first five hairs were not significantly different from the average indices of the second five or from the third group of five hairs from the same sample. It was decided therefore to take measurements on five hairs at both the 0° and 90° positions from each yearly sample of each subject beginning at birth and extending to the present. The two sets of readings for these five hairs were each averaged and the averages recorded as the refractive indices for the given yearly sample.

OBSERVATIONS

Indices of refraction for hair of all subjects at each age level with the substage polarizer set at 90° or perpendicular to the hair are presented in table 1. Table 2 is a tabulation of data with the hair and substage polarizer parallel or set at 0° . Table 3 records the birefringence obtained in each instance by subtracting the lower or 90° reading from the higher or 0° reading.

Variation of index with age. An examination of the data reveals that the first two years of life is a period of marked fluctuation of refractive indices. The index for the group as a whole with the substage polarizer at 0° is low at birth, rises sharply during the first year, drops during the second

TABLE 2

Average refractive index of 5 hairs from each yearly sample of subjects with substage polarizer at 0°
(N.B.: Each figure should be preceded by 1.5, e.g., the index of subject A at birth is 1.5537)

[illegible]

TABLE 3
Average birefringence of 5 hairs from each yearly sample of subjects
 (N.B.: Each figure should be preceded by .00, e.g., the birefringence of subject A at birth is .0039)

AGE	BOYS										GIRLS									
	A	C	F	G	K	O	P	B	D	E	H	I	J	L	M	N				
<i>Years</i>																				
B	39	37	21	40	41	50	24	43	32	24	29	40	..	54	49	41				
1	86	64	49	33	73	64	44	75	44	35	56	43	76	54	53	60				
2	93	66	43	23	65	46	49	84	47	38	55	59	62	47	61	61				
3	81	41	59	30	80	38	57	87	70	52	68	58	44	52	89	67				
4	73	46	36	45	63	73	50	86	66	41	48	67	53	47	77	55				
5	83	42	34	50	57	47	54	75	58	48	47	63	44	64	67	63				
6	85	48	56	44	54	49	46	86	52	38	48	66	34	65	64	59				
7	76	53	59	49	49	46	53	69	58	45	71	54	40	60	71	53				
8	82	40	60	43	57	61	51	73	62	29	52	61	40	82	65	60				
9	80	51	54	48	49	51	42	53	61	56	83	56	39	82	67	64				
10	87	49	67	52	44	41	58	72	66	34	43	53	51	63	53	48				
11	91	47	60	55	51	47	..	108	53	68	66	49	54	62	77	57				
12	88	56	69	55	56	47	..	81	49	47	50	60	41	60	63	56				
13	84	45	53	41	67	47	..	89	65	50	52	72	41	53	71	68				
14	88	43	51	46	42	46	..	89	61	24	39	48	78	..	..	90				
15	81	41	60	..	46	..	..	88	55	44	54	73	74	..	..	..	
16	84	40	41	..	54	..	..	79	83	21	90	43	67	..	..	..	
17	90	37	48	..	..	..	..	89	44	35	..	..	..	..	..	..
18	90	44	..	..	..	..	..	94	..	..	..	..	..	..	..	..
19	92	33	..	..	..	..	..	..	..	..	..	..	..	..	..	..
20	71	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

year and then for the next four years exhibits a tendency to remain quite constant. With the substage polarizer at 90° , however, the birth samples reflect a comparatively high index of refraction but during the first year the index drops. This drop continues with little interruption throughout the 18 years. The birefringence is lowest at birth and after the first year it remains somewhat constant with a slight tendency to increase with age.

No index is found below 1.5548 at the 0° position during the first 7 years for any subject, but after 7 years of age approximately one-half of the subjects fall below this figure. Similarly at the 90° position all but 5 of the readings are above 1.5500 for the first 7 years while approximately one-half of the readings after 7 years of age are below. Readings above 1.5610 are found only during the first 8 years.

Variation of index with sex. No sex difference is apparent between the averages of either the 0° or 90° data within the first 7 years. During this period there is a tendency for the indices of both sexes to correspond rather closely. After 7 years there is a tendency for the indices of the girls to drop below that of the boys. This difference between sexes is presented in the form of a graph, figure 1.

The trends in refractive indices of individuals according to age at the 0° position parallel closely the 90° readings. The trends in index at the 90° position are illustrated in figure 2. During the early years the trends of both boys and girls are more or less horizontal. At the period between 7 and 9 years a general drop occurs but on closer observation it may be seen that the indices of the girls drop to a greater extent than those of the boys (tables 1 and 2). To be more specific the indices of all but two of the girls show a drop at 7 years which is carried even farther after 9 years of age whereas the indices of the boys drop more gradually during this corresponding period and do not reach as low a level.

Variation of index. The averaged indices for hair of a given individual may be observed to differ from the average indices of other subjects at the same age level (tables 1, 2

and fig. 2). Subject E, for example, maintains average indices of refraction far below the readings for subject C, whereas the twins, L and M, maintain indices entirely different from those exhibited by subjects O, A and G. Likewise, there is little similarity in the patterns followed by subjects J and P. The greatest similarity in indices is reflected in the readings for the twins.

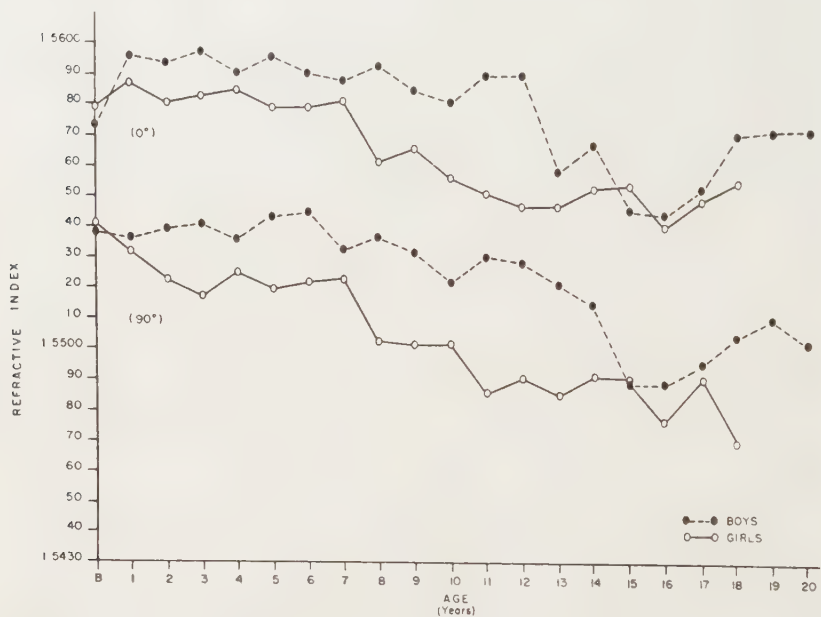


Fig. 1 Average refractive indices according to sex, age and position of sub-stage polarizer.

Birefringence is low at birth, rises rapidly during the first year after which it remains somewhat constant for any given subject (fig. 3). The pattern for the birefringence of one individual may also differ markedly from that followed by another. Subject A, for example, maintains a birefringence of about .0080 while subject G fluctuates between .0025 and .0050.

There is a wide range of indices of individual hairs from any given subject. The detailed study of subject A mentioned above provides information concerning the range in

indices that occur within each year for one subject as well as the amount of fluctuation between yearly samples from birth through 20 years. The findings may be summarized as follows:

1. At 0° it was found that the greatest range recorded for the 15 hairs at a given age level was .0047, while the greatest range in index between yearly samples for the entire 20 years was .0071. The smallest range at a given age was .0009 and the average for all samples for all years was .0031.

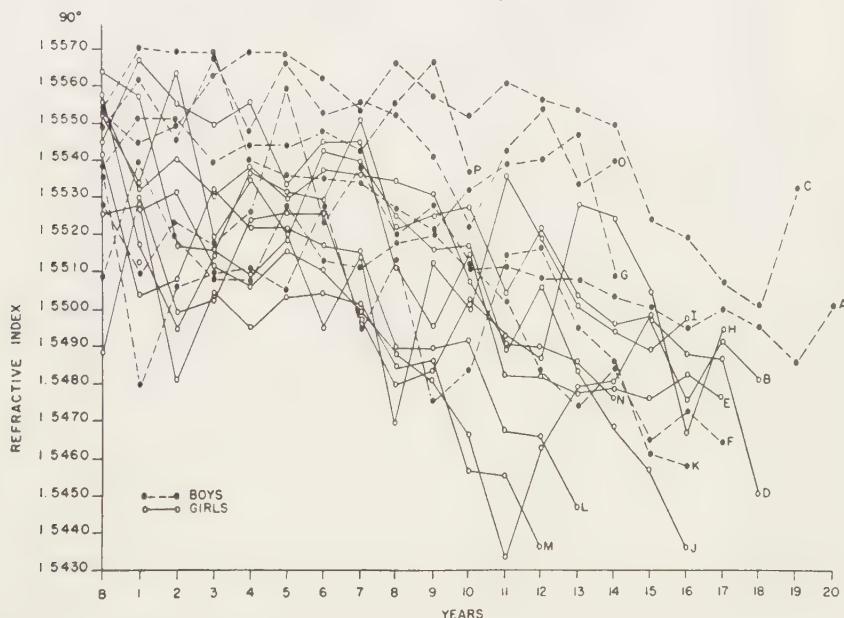


Fig. 2 Individual trends of refractive indices for boys and girls according to age with the substage polarizer set at 90° .

2. At 90° the greatest range for the samples of any one year was .0067, while the greatest range for all years was .0076. The smallest range for any one year was .0006, while the average for all years was .0029.

3. The greatest range in birefringence at any one age level was .0059 while the greatest range between age levels was .0096. The smallest deviation was .0017 and the average for the group was .0036.

*Statistical analysis.*⁴ A rough test of normality was conducted which consisted of plotting the yearly ranges of indices of refraction obtained at 90° against the means (fig. 4) in order to determine the specific type of analysis to be employed. The range of indices for a given age is independent of the mean index of that age indicating that an analysis of variance can be applied safely. Similar conclusions were reached after a survey of the 0° and birefringence data.

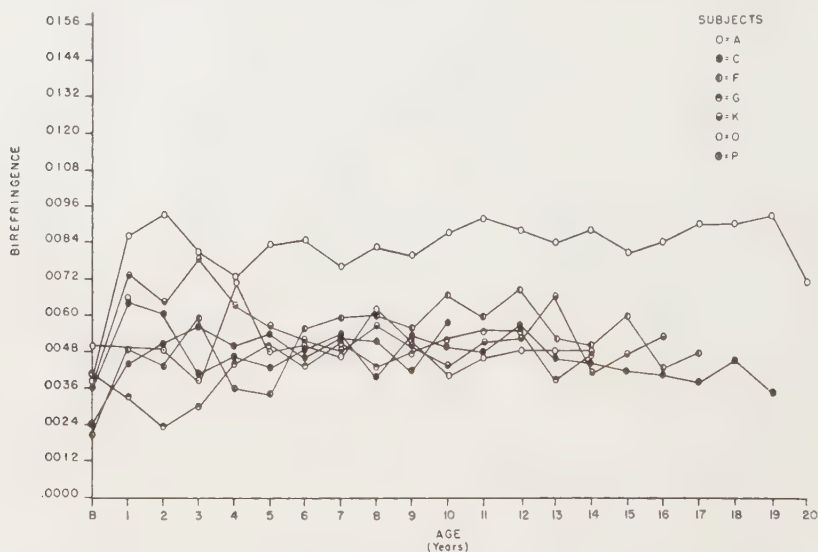


Fig. 3 Individual trends of birefringence for boys according to age.

The first analysis of variance was applied to the data obtained at 90° for the entire group of 7 boys and 9 girls between the ages of one and thirteen years. (The readings obtained at birth were omitted from the statistical analysis because of their marked differences from the succeeding yearly data.) The results of this analysis are summarized in table 4. The differences between sexes were investigated as well as the differences between ages for boys and girls and the differences between individual boys and individual girls.

⁴ The statistical analysis was conducted by Vernice L. Watts.

The technique of obtaining that part of variation due to regression between two variables by utilizing a set of orthogonal coefficients (Fisher and Yates, '48) was used. In the entire group between the ages of one and thirteen years observations for three years are missing for one boy. These blanks were filled in by a formula given in *Statistical Methods* by

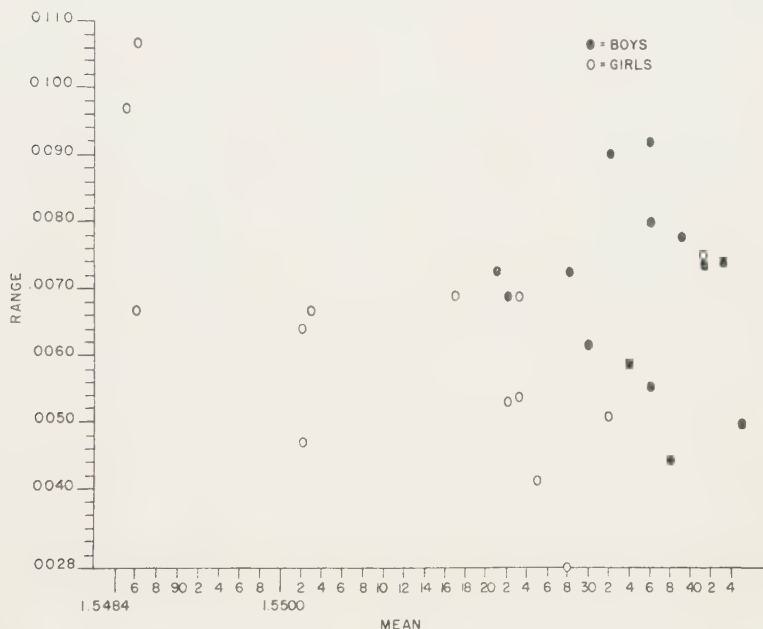


Fig. 4 Scattergram of yearly mean indices of refraction of boys and girls for first 13 years with substage polarizer set at 90° position, plotted against the range of indices from which each mean was determined.

Snedecor ('46) and the total degrees of freedom were decreased by three, which was taken from the interaction term of boys with years. By this procedure all variation was restricted to a class under sources of variation leaving no residual variation to be used as an error term. The regression was applied, therefore, and the higher orders of regression were used as an error term. All regression terms and interactions of fourth degree and above were pooled to give an error term of one hundred forty-nine degrees of freedom.

TABLE 4

Analysis of variance of refractive indices at 90° classified according to sex, age (one through 13 years) and individuals within sexes

SOURCE OF VARIANCE	DEGREES OF FREEDOM	MEAN SQUARE	F RATIO
Sex	1	25,698.962	75.462**
Age			
Boys			
Linear regression	1	19.390	< 1
Quadric regression	1	325.101	< 1
Cubic regression	1	49.128	< 1
Quartic regression	1	1,126.649	
Quintic regression	1	372.441	
Deviation from quintic	7	1,698.703	
Total	12	1,148.636	3.37**
Girls			
Linear regression	1	23,392.002	68.69**
Quadric regression	1	524.446	1.54
Cubic regression	1	.212	< 1
Quartic regression	1	562.485	
Quintic regression	1	111.955	
Deviation from quintic	7	344.302	
Total	12	2,250.101	6.61**
Among boys	6	3,817.172	11.21**
Among girls	8	2,594.884	7.62**
Interactions			
Boys × years linear	6	743.761	2.18*
Boys × years quadric	6	1,723.457	5.06**
Boys × years cubic	6	977.282	2.87*
Boys × years quartic	6	431.083	
Boys × years quintic	6	1,863.493	
Boys × years remainder	39	67.519	
Total	69	537.213	1.58*
Girls × years linear	8	1,317.395	3.87
Girls × years quadric	8	277.864	< 1
Girls × years cubic	8	654.422	1.92
Girls × years quartic	8	527.201	
Girls × years quintic	8	256.881	
Girls × years remainder	56	158.400	
Total	96	345.213	1.01
Error ¹	141	340.555	

In this and succeeding tables * indicates significance at 5% level and ** indicates significance at or below the 1% level.

¹ The error term in this and succeeding tables is derived by pooling the sum of squares from all the regressions and interactions of 4th degrees and above. The degrees of freedom are determined by summing the degrees of freedom from each term contributing to the error of the sum of squares.

The hypotheses to be tested and the results are as follows:

- H₁ There is no difference between sexes. This hypothesis can be rejected at both the 5% and 1% levels of significance.
- H₂ The population regression coefficient for boys with respect to age is zero. This hypothesis cannot be rejected. No evidence was found of any type of regression relationship in this example.
- H₃ There is no difference between ages for boys. This hypothesis can be rejected at the 5% and 1% levels. The differences, however, appear to be random fluctuations from year to year. An examination of the interactions for boys with age shows that the interactions for the first three degrees of regression are all significant at the 5% level. This indicates that any regression existing in any one boy would be different from that in another.
- H₄ There is no difference between ages for girls. This hypothesis can be rejected at both the 5% and the 1% levels.
- H₅ The population regression coefficient for girls and ages is zero. This hypothesis can be rejected at both the 5% and 1% levels.

An examination of table 4 reveals several additional facts. The strong linear regression for the group of girls is not followed by each individual as is shown by a very significant interaction with linear regression. It is observed that most of the difference between years is concentrated in this linear regression term. Due to indications from other sources as well as from the data, the possibility is suggested that this strong linear trend comes from a few of the girls in the older years. Whether this effect is a direct result of age or only related in some distant way was not immediately determined. However, the contribution to this trend which might be attributed to the effect of age was eliminated when the analysis was repeated omitting the ages eleven, twelve, and thirteen (table 4 a). Although the variation among individuals

was reduced markedly the results are still significant at both the 5% and 1% levels. The variation between years due to linear regression was also reduced to a much smaller amount though still significant at both the 5% and 1% levels. The interaction term is no longer significant indicating that the general linear trend is followed fairly well throughout the sample.

TABLE 4a

Analysis of variance of refractive indices at 90° of girls (from one to 10 years)

SOURCE OF VARIANCE	DEGREES OF FREEDOM	MEAN SQUARE	F RATIO
<i>Age</i>			
Linear regression	1	6,894.150	16.22**
Quadric regression	1	67.892	< 1
Cubic regression	1	88.217	< 1
Quartic regression	1	571.078	
Quintic regression	1	7.405	
Deviation from quintic	4	1,753.936	
Total	9	1,042.520	2.45*
Among girls	8	2,029.470	4.78**
<i>Interactions</i>			
Girls × years linear	8	426.925	1.005
Girls × years quadric	8	220.258	< 1
Girls × years cubic	8	19.143	< 1
Girls × years quartic	8	434.259	
Girls × years quintic	8	128.094	
Girls × years remainder	32	256.269	
Total	72	254.417	< 1
Error	54	424.974	

In table 5 the parallel or 0° data are analyzed in a similar way. The same general trend appears that is present in the 90° readings. A very significant difference is exhibited between sexes, the girls having a very strong linear trend between years and also a very significant interaction indicating the same effect as that shown in table 4. In addition, table 5 indicates a significant F ratio for linear regression for boys between ages. The interaction term is significant at both the

TABLE 5

*Analysis of variance of refractive indices at 0° classified according to sex, age
(one through 13 years) and individuals within sexes*

SOURCE OF VARIANCE	DEGREES OF FREEDOM	MEAN SQUARE	F RATIO
Sex	1	21,527.438	172.14**
Age			
Boys			
Linear regression	1	1,648.038	13.18**
Quadric regression	1	34.269	< 1
Cubic regression	1	3.934	< 1
Quartic regression	1	103.436	
Quintic regression	1	287.577	
Deviation from quintic	7	102.485	
Total	12	232.888	1.86*
Girls			
Linear regression	1	22,272.039	178.09**
Quadric regression	1	994.936	7.96**
Cubic regression	1	318.757	2.55
Quartic regression	1	326.418	
Quintic regression	1	96.479	
Deviation from quintic	1	157.927	
Total	7	2,092.843	16.73**
Among boys	6	3,127.770	25.01**
Among girls	8	1,132.829	9.06**
Interactions			
Boys × years linear	6	492.529	3.94**
Boys × years quadric	6	991.950	7.93**
Boys × years cubic	6	117.277	
Boys × years quartic	6	72.590	
Boys × years quintic	6	534.792	
Boys × years remainder	39	99.706	
Total	69	222.376	1.78**
Girls × years linear	8	1,031.326	8.25**
Girls × years quadric	8	344.146	2.75**
Girls × years cubic	8	802.209	6.41**
Girls × years quartic	8	331.404	
Girls × years quintic	8	84.961	
Girls × years remainder	56	105.780	
Total	96	277.875	2.22**
Error	141	125.058	

TABLE 6

*Analysis of variance of birefringence classified according to sex, age
(one through 13 years) and individuals within sexes*

SOURCE OF VARIANCE	DEGREES OF FREEDOM	MEAN SQUARE	F RATIO
Sex	1	577.177	9.16**
Age			
Boys			
Linear regression	1	39.356	1.75
Quadric regression	1	110.123	1.37
Cubic regression	1	86.124	
Quartic regression	1	8.018	
Quintic regression	1	82.728	
Deviation from quintic	7	18.167	
Total	12	37.794	1
Girls			
Linear regression	1	50.637	1
Quadric regression	1	.272	1
Cubic regression	1	142.667	2.26
Quartic regression	1	141.273	
Quintic regression	1	70.394	
Deviation from quintic	7	161.822	
Total	12	128.167	2.03*
Among boys	6	2,239.579	25.54**
Among girls	8	1,383.220	21.95**
Interactions			
Boys \times years linear	6	264.248	4.19**
Boys \times years quadric	6	129.456	2.05
Boys \times years cubic	6	127.927	2.03
Boys \times years quartic	6	35.117	
Boys \times years quintic	6	48.855	
Boys \times years remainder	39	55.774	
Total	69	84.186	1.34
Girls \times years linear	8	112.756	1.79
Girls \times years quadric	8	187.336	2.97**
Girls \times years cubic	8	319.616	5.07**
Girls \times years quartic	8	82.405	
Girls \times years quintic	8	67.379	
Girls \times years remainder	56	61.509	
Total	96	100.005	1.59**
Total	204		
Error	141	63.008	

5% and 1% levels indicating that this trend is not followed throughout by the boys.

In both the 90° and 0° readings the differences among girls and among boys are significant at the 5% and 1% levels. The question immediately arises concerning how much of the difference between sexes is due to the strong linear trend introduced by the girls between the ages of ten and thirteen. Of the data for the girls from one to ten years, the mean square due to variation between sexes was calculated. The F ratio for this mean square is 89.36 which is even higher than before the older subjects were withdrawn thus indicating that the difference between sexes is independent of the strong linear trend exhibited by the older girls.

Since the 90° and 0° readings represent extremes, an analysis of the difference between them or the birefringence was conducted in order to determine the degree to which one reading is similar to the other. In table 6 the analysis of this birefringence is recorded. The difference between sexes is significant at both the 5% and 1% levels which indicates that one sex has a greater range of extreme values than the other. The girls show a greater range than the boys. The linear regression term for both boys and girls between ages is not significant.

DISCUSSION

The refractive indices of hair are direct indications of its chemical composition and structure, thus it is logical to hypothesize that the refractive indices might vary to a limited extent from hair to hair on a given individual's head, that there might be even more marked variation between hair of individuals whose metabolic processes are significantly different and that fluctuations according to sex and age, produced by differences in endocrine function, might also be evident. This longitudinal study of refractive indices of the cuticle of hair involves a series of hair samples from the same individuals obtained over an extended period of time.

The average refractive indices indicate that the first and second years represent a period of fluctuation. This is in

agreement with previous studies of the same samples relative to size (area of cross-section), index (shape of cross-section), scale count, and medullation. Here, too, it was observed that the birth, first and second year samples exhibited marked variations. In those instances it was suggested that the great irregularity in hair during this early period was due primarily to the changes in the type of hair, i.e., the change from the lanugo or prenatal hair, to the vellus or fine postnatal hair, to the intermediate and terminal types. Changes in refractive indices and birefringence may well be associated with changes in the composition of the hair of these various types.

The tendency for refractive indices to remain relatively constant between the second and seventh years, with no marked sex differences, indicates that the type and composition of hair for both boys and girls is rather stable during this period. A marked difference between sexes is first indicated immediately after the seventh year when the hair of five of the girls shows sharp drops in indices. By nine years of age the hair of two more of the girls has followed in this downward trend. Subject D does not change in this respect until 16 years of age after which the refractive indices of her hair present very sharp and continuous drops. The hair of subject B presents decided drops at eight and nine years after which the indices show an upward trend more closely approximating that of the boys. The sharp drops in the indices of the girls' hair suggest a change in composition of the hair possibly reflecting the effect of glandular changes associated with puberty. During this same period the hair of the boys makes slow but steady drops in refractive indices with no marked trends or fluctuations until 12 to 14 years of age, when their hair, too, begins to drop rather sharply in refractive indices. At 15, 16 and 17 years of age the indices of both boys and girls rather closely parallel each other with both sexes beginning to rise in indices after 16 years.

The effect of permanent waving solution on hair must not be overlooked since it is known that prolonged treatment

with harsh waving solutions will produce lower refractive indices. Fortunately, for this study, such treatment of hair is less often applied to children than to adults. When applied it is the free ends of the hair that are most commonly treated. None of the samples appeared grossly to have undergone such treatment. And finally, it was the proximal ends of the hair which were taken for examination.

The sex trends indicated in this study are in direct conflict with data obtained by Greenwell, Willmer and Kirk. In their study it was the hair of girls which presented refractive indices higher than those of boys except in the few instances where pre-adolescent boys displayed an index even higher than that for most of the girls. Kirk (personal communication, '47) has pointed out that the oils used in their study were calibrated too low due to a defect in the refractometer. However, it would seem that this would affect all of the readings equally and would not influence the relative indices of the boys and girls. Also, the majority of subjects studied by Greenwell, Willmer and Kirk were post-adolescents, but this fact should not reverse the position of the males and females with regard to index. In their study an index of refraction (presumably a figure between the 0° and 90° positions) was determined partially by use of oblique illumination and partially by use of the Becke line with normal illumination. This difference in technique should not affect the relative positions of the readings for males and females. Greenwell, Willmer and Kirk also suggest that rather abrupt changes occur in hair of males during puberty with no indication of a similar change in females. The data for the sixteen subjects of this study suggest marked fluctuations for the girls beginning several years prior to puberty and a corresponding change, but less marked, in the boys at a time closer to puberty.

Another factor which should be considered in interpreting the present data is the effect of storage of the hair upon its indices of refraction. Greenwell, Willmer and Kirk found, in those instances in which hair had been stored, that the

index of the hair dropped with storage and that the drop was roughly proportional to the time the hair had been stored. A limited study extending over just three years was undertaken to investigate this point. The refractive indices of hair of two subjects were measured at the time of its arrival in the laboratory. It was then stored and after three years remeasured. No significant changes were found since the differences in refractive indices between the first and second observations were well within the error of the procedure. Upon examining the data as a whole it is observed that the birth, first and second year samples, which have been stored the longest have, in fact, the highest indices. This finding would indicate an increase in refractive indices with storage if storage contributes to change of refractive indices. Since all hairs were stored under similar conditions and were treated in the same manner by agitating for fifteen minutes in ether and alcohol, it is believed that any effect of storage has been minimized.

The question of the determination of the age of an unknown individual by the examination of a questioned specimen of hair has long been considered of importance in the individualization of hair. To date there has been very little information about hair upon which an estimate of age could be based. The present study indicates that refractive indices will not be of value in determining the exact chronological age of a questioned hair. However, the data presented in tables 1 and 2 as well as in figures 1 and 2 suggest that in some instances, at least, the general age period may be determined. From the 0° data it may be assumed that a hair with an index less than 1.5548 probably came from an individual older than seven years. Similarly at 90° a hair below 1.5500 probably would not be from a young child. On the other hand there is a strong probability that a hair with an index over 1.5595 at 0° or over 1.5540 at 90° came from a child under 14 years of age. Due to the limits of this investigation these figures cannot be treated as conclusive but

merely as indicative until more corroborating data can be obtained.

The problem of sex determination from hair on the basis of its indices is an interesting one. Greenwell, Willmer and Kirk indicate that in about 80% of the total cases studied by them, the refractive index might be considered to be conclusive for the sex of the individual. They found no hair from females with a mean refractive index below 1.5480 and none from males above 1.5490. The mean refractive index for all boys at the 0° position in this study is 1.5583, while for girls it is 1.5565. The corresponding means at 90° for the boys is 1.5530 and for the girls 1.5519. The average index at both positions for the boys is 1.5556 while for the girls it is 1.5542.

The statistical analysis of these data reveals a sex difference in the refractive indices which is significant at the 1% level. This fact is shown in the scattergram, figure 4, on which the mean is plotted against the range of indices of refraction for the two sexes for the first 13 years. The tendency for the indices of most of the girls to fall below those of the boys is quite apparent. Since the pre-adolescent group is included in the total populations it was thought that this might be a factor in causing the limited overlap between the sexes as indicated in figure 4. A closer examination of the data reflects that in every instance where the data for a girl fall within the range of those for the boys, the overlap is occasioned by a reading obtained before the eighth year. For example, the symbol for the girls at the extreme right of the scattergram (1.5541-.0076) represents the birth readings while the next symbol for the girls (1.5532-.0051) is that for the first year readings, etc. The symbols for the girls do not overlap the symbols for the boys. Although the data are too limited in this study to predict the percentage of individuals whose sex could be determined on the basis of refractive indices of hair, a significant sex difference in hair is indicated. Birefringence may also be of some value in determining the sex of the individual from whom a questioned hair came since the sex difference in birefringence was also

significant at the 1% level. The average birefringence for the boys is .0054 while for the girls it is .0060.

The value of refractive indices as a criterion in the individualization of hair is very questionable. Among the sixteen subjects in this study, ranges of as much as .0067 were found between hairs of the same individuals at the same age level. This figure, of course, is extreme with the average range of index at a given age being approximately .003. When at least five hairs from a questioned sample are to be compared with five or more hairs of a known sample, it is believed that, if the average index of one sample varies more than .005 from the average index of the other, the two samples did not come from the same source. However, since in a large number of cases the indices of two samples fall within the .005 limitation, elimination on the basis of refractive index can be made only in extreme cases.

Birefringence in certain instances may also be of limited value in hair individualization. Birefringence after the first two or three years of age has a tendency to remain more or less constant for a given individual and although many individuals correspond rather closely with regard to birefringence, others have quite characteristic birefringence as illustrated by subject A in figure 3. Subject A, who maintains an average birefringence of about .0080 could be differentiated easily from subject G whose birefringence fluctuates between .0030 and .0050. It would appear that birefringence and refractive indices, like so many other characteristics of hair, may be utilized for elimination purposes but may not be useful in the positive individualization of hair.

SUMMARY AND CONCLUSIONS

Refractive indices and birefringence of the cuticle of hair have been determined by means of the double variation method on a series of samples from the vertex of 16 white children, 7 boys and 9 girls. The subjects provided monthly samples of hair over a period of time extending from birth to 20 years for the oldest. Observations include readings on 5 hairs from

each yearly sample for each subject. Differences, as well as similarities, between sexes, together with differences between individuals of the same sex, were studied. This longitudinal study also presents evidence pertaining to age changes. Statistical analysis of the data supports the preliminary observations regarding sex, age and individual variations.

The following conclusions are drawn:

1. The refractive indices of the cuticle of hair fluctuate markedly during the first two years of life, probably due to the transition from pre-natal lanugo to post-natal terminal hair. Between the third and seventh years the refractive indices of boys and girls approximate each other rather closely with no evidence of divergence according to sex.

2. After the eighth year and extending to the sixteenth year there is a sharp drop in refractive indices of the hair of girls during which period their indices fall well below the levels of those for boys. During the first five years of this period the indices of the boys drop rather slowly after which they also decline sharply. After 16 years of age the refractive indices of the hair of boys and girls approach each other again with the girls presenting slightly lower indices.

3. Refractive indices of hair may be of value in indicating the approximate age and sex of the individual. A very high index suggests a child under 7 years of age whereas hair with a low index is more likely to be from a girl over 8 or 9 years of age.

4. Individual differences in indices are apparent in the data. However, the range in indices for some of the subjects is so wide that individualization of hair on the basis of refractive index alone, except in unusual cases, is of doubtful value.

5. Statistical analyses of variance are based on data between 1 and 13 years at both the 0° and 90° positions and the birefringence. These analyses reflect that age, sex and individual differences are significant for all three factors at both the 5% and 1% levels.

6. Fluctuations in refractive index with age were found to be random for the boys. However, a strong linear regression relative to age was found for the girls, suggesting a possible association with puberty.

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PHOTOELECTRIC MEASUREMENT OF SKIN COLOR IN A MEXICAN MESTIZO POPULATION

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The purpose of the present study is to test the applicability of a photoelectric reflection meter to the study of skin color. Reflectance values recorded with a portable instrument have been used to compare the skin color of the indigenous population of a town in Mexico with that of its people who have only recently come to live there. The study involves the initial application of this type of apparatus to the measurement of skin color in anthropological field work. Subjective descriptions and color chart or color top matching may be adequate for comparing skin color in groups of people that contrast sharply in this respect; they are inadequate methods for differentiating similar skin colors. On the other hand, the recording spectrophotometer, an instrument which has been applied to the exact description of skin color, is too cumbersome for use in field situations. The problem was to develop a method which will permit the quantification of the amount of light (of a few specified wave lengths) reflected from selected sites of skin. Such a method has been adapted from one previously used at the Institute of Human Biology at the University of Michigan.

METHOD

The instrument used in the present study is a "Photoelectric Reflection Meter, Model 610" manufactured by the Photovolt Corporation, New York City. It consists of two units: (1) the main unit which comprises the indicating galvanometer, the controls, and the built-in constant voltage transformer and (2) a search unit which houses a lamp and

the photocell. The light of the lamp passes through an exchangeable glass color filter of known optical property, and through an aperture in the photocell, and then impinges on the surface to be measured. The light which is diffusely reflected from the surface acts on the photocell.

The instrument is designed to be operated either on an alternating current power line or on a storage battery of automobile type. The built-in constant voltage transformer serves the purpose of minimizing the effect of voltage variations in the power line. However, in our work in Mexico, some fluctuation of the galvanometer needle, and consequent loss of precision in the readings, resulted from fluctuations in the local power or deviations in frequency of the alternating current. On a future study under such field conditions we would use a storage battery. Before every second reading the instrument was standardized with the aid of white or gray enamel plaques, which had been previously calibrated in terms of magnesium oxide so that it is possible to report all results in terms of the absolute reflectance scale in which magnesium oxide is taken to represent 100%.

The color filters are produced from glass manufactured by the Corning Glass Works, Corning, New York. The red filter consists of Corning glass no. 2403 ground to a thickness of 5 mm; the green filter is Corning no. 4010, 3 mm thick; and the blue filter is Corning no. 5543, 2 mm thick. With regard to the spectral characteristics of these filters of the indicated thickness, Mr. F. Lonberg of the Photovolt Corporation states:

"The color filters have peak transmission values at 420, 525, and 650 millimicrons. The spectral band isolated by the filters is approximately 80 millimicrons wide. The lamp of the Reflection Meter burns with a color temperature of approximately 3000°K. The spectral emission curve of a black body at this temperature has a considerable slant in the sense that it rises from the blue to the red part of the spectrum. This has the result that the 'effective' transmission of the filters, i.e. the filter curves multiplied by the emission curve of the lamp, give peak values that are shifted somewhat in the direction of the longer wavelength values, but this effect cannot be more than 10 to 12 millimicrons. Also, the shifting

effect of the lamp emission curve is counteracted, in the red part of the spectrum, by the opposite slant of the spectral response curve of the photocell. In the blue and the green part of the spectrum, the slant of the photocell curve is not very pronounced and can be disregarded in this connection, but the slant in the red approximately balances the effect of the slant of the lamp emission curve. Therefore, taking into consideration the filter itself, the lamp, and the photocell, we feel it is safe to say that the measurements are carried out at 430, 535, and 650 millimicrons."

In selecting sites of skin for study three considerations present themselves: the areas should be free of pigmented hairs, they should be clean, and they should be accessible and present a flat surface to the search unit. As an example of such an area in a region frequently exposed to sunlight, the middle of the forehead above glabella was examined. As an example of an area little exposed to sunlight but still easily accessible, the groove corresponding to the medial intermuscular septum in the middle third of the inner surface of the upper arm was selected. Pigmented hairs sometimes grow in the latter area in adult white males but not in any of the children who were studied in Mexico.

SAMPLE

The sample consists of 243 school children in Paracho, Michoacán, Mexico. Paracho is a town of some 4,000 persons and is located in the heart of the Sierra region of the Tarascan Indians. Nevertheless, even before the coming of an automobile road, the people of the town, and indeed of the whole region, had become more or less *mestizoized*. Only a minority of the people continue to understand and use the Tarascan language. American Indian physical traits predominate, however, although clear evidence of European admixture is also apparent (Lasker, '53).

Three groups of children were examined between August 29 and September 11, 1952. These consisted of all the available students in the federal secondary school, the children in the upper grades of the larger of the two federal primary schools,

TABLE 1
Light reflectance from skin of Mexican school children
 Means and standard errors (in per cent of reflectance from magnesium oxide)

NUMBER	AGE (YEARS)	FOREHEAD (CENTER)						ARM (INNER ASPECT)								
		430 m μ blue			535 m μ green			430 m μ blue			535 m μ green					
		Mean	S.E.		Mean	S.E.		Mean	S.E.		Mean	S.E.				
Male																
I Internado	86	15.64	0.23		14.14	0.29		37.20	0.50		15.85	0.34	19.82	0.39	43.59	0.50
II Parachoan	41	14.63	0.33		16.16	0.44		39.78	0.66		16.39	0.46	20.64	0.56	44.68	0.75
III Other	44	13.91	0.30		16.79	0.47		40.33	0.54		17.03	0.42	21.57	0.49	46.08	0.63
Female																
IV Parachoan	46	14.48	0.27		16.86	0.43		42.00	0.65		16.90	0.51	21.20	0.62	44.13	0.77
V Other	25-26	14.19	0.47		18.33	0.54		42.92	0.75		18.40	0.55	23.06	0.72	45.98	0.80
Intergroup differences between																
II and I		- 1.01*	0.40		2.02*	0.53		2.58*	0.83		0.54	0.57	0.82	0.68	1.09	0.90
III and I		- 1.73*	0.38		2.65*	0.55		3.13*	0.74		1.18*	0.54	1.75*	0.63	2.49*	0.80
III and II		- 0.72	0.45		0.63	0.64		0.55	0.85		0.64	0.62	0.93	0.75	1.40	0.98
V and IV		- 0.29	0.54		1.47*	0.69		0.92	0.99		1.50	0.75	1.86	0.95	1.85	1.11
IV and II		- 0.15	0.43		0.82	0.51		2.22*	0.93		0.51	0.69	0.56	0.84	- 0.55	1.07
V and III		0.28	0.56		1.37*	0.66		2.59*	0.92		1.37	0.69	1.49	0.87	- 0.10	1.02

* Statistically significant at the 5% level of probability.

and all the available boys in the federal *Internado* (boarding school) for Tarascan indigenes. Persons under 10 years of age or over 20 (calculated to nearest birthdays) were excluded from consideration.

The series of observations taken in the day schools were pooled. Forty-one boys and 46 girls are the offspring of Paracho-born parents. In addition, 44 boys and 26 girls have one or both parents born in another community, and these are distinguished from the Parachoans and designated as "other" in table 1. The places of birth of the parents in these cases are, for the most part, in the same region of the state of Michoacán. Most of these places are moderately large or large "Mestizo" towns. Fewer of the children have parents from "Indian" villages. When one separates children whose parents are from Mestizo towns and those whose parents are from Indian villages, the former are, on the average, lighter in skin color than the Parachoans, and the latter are darker. Such differences are not statistically significant, however, and also in view of the arbitrariness of the categorization of some places as Tarascan or Mestizo, no reliance will be placed on such a distinction.

The 86 boys in the *Internado* series are sons of parents from places other than Paracho. The school was founded for the education and occupational training of Tarascans, and most of the students are Tarascans. Of the boys examined there, only 10 would be classed as Mestizo on the basis of place of birth and lack of knowledge of the Tarascan language. Although these Mestizos have, on the average, a lighter skin color than the others, the number is too small to yield significant results if analyzed separately.

FINDINGS

Between the ages of 10 and 20 inclusive, there is no evidence of significant age trends in reflectance values from skin of either forehead or arm in either the boys or girls of the present series. Slight differences in average age are therefore of no significance in evaluating different series.

Boys are, on the average, slightly darker than girls. These differences are statistically significant, however, only for the skin of the forehead in respect to 650 m μ (red) light in the Parachoans and in respect to all wave lengths in the "others" (see table 1). Because this difference is apparent in skin which is exposed to sunlight but not in the protected skin of the inner arm, the observed sex differences may be caused by differences in degree of exposure of the forehead to sunlight between the sexes. Children of both sexes normally go hatless in Paracho, but girls may spend less time outdoors in the sun.

The boys in the Internado have darker skin than boys in the day schools. This shows in significantly less reflectance at all wave lengths in comparison with Parachoan boys as far as forehead is concerned, and for both forehead and inner arm in comparison with "other" boys. Again, differences in degree of exposure to sunburn and tanning may be partly responsible, although there is no direct evidence to suggest differences in activity which would have such an effect. Alternatively, the students in the Internado are known to possess, on the average, a smaller fraction of Spanish ancestry; they were selected for this educational opportunity because they were considered to be "Indian," a term, it is true, which in Mexico may have more to do with socio-cultural factors than with biologic race (Kaplan, '53).

Among the students in the day schools no systematic differences in degree of exposure to sunlight could be postulated to account for any differences in skin color between the children of Paracho-born parents and those of parents from other places. Nevertheless, the Parachoan children show less average reflectance from both forehead and inner arm for both sexes and all wave lengths of light. The differences are statistically significant only for the forehead of females with the green filter, but the differences in inner arm reflectance nearly approach the 5% confidence limit. As the differences in males further confirm the same tendency, it can be said that the children of natives to Paracho are darker

in skin color than those of people who have come to settle in Paracho recently. As the boys in the Internado are still darker one can recognize a gradient: children from the Tarascan villages are darkest, those of Paracho intermediate, and newcomers from other places somewhat lighter.

CONCLUSIONS

An objective photoelectric recording of light reflectance from skin permits the assessing of small differences in average skin color such as occur in communities with varying degrees of mixture between American Indian and European ancestors. In applying such a technique to school children in Paracho, it is seen that boys attending the school for indigenes of the region are darkest on the average, children of parents native to the town are intermediate, and children of parents who were born elsewhere are lightest. Although these differences are apparently ascribable to different proportions of European and Amerindian ancestry, the instrument is delicate enough to record differences in the degree of tanning caused by differences in exposure to the sun. This latter fact may explain the observation that the boys tend to be somewhat darker in skin color than the girls.

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- A serum containing anti-s and anti-Jk^b Ruth Sanger and R. R. Race; R. E. Rosenfield and P. Vogel
 A further example of anti-Jk^a Mia van der Hart, J. J. van Loghem, Jr.
 An anti-Rh serum reacting differently with O and with A red cells Elizabeth W. Ikin, A. E. Mourant, V. W. Pugh
 Acquired haemolytic reaction in a newborn C. J. A. Bakx, J. J. van Loghem, Jr., Willy Klomp-Magnee
 Preservation of erythrocytes for blood group determination L. E. Nijenhuis
 Studies on the occurrence of leucocyte antibodies (II) R. Goudsmit, J. J. van Loghem, Jr.

BRIEF COMMUNICATIONS

STRUCTURE AND RELATIONSHIPS OF MEGANTHROPUS AFRICANUS

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THREE FIGURES

Many remains of fossil mammals were found by Professor Kohl-Larsen before the war in East Africa southeast of Lake Victoria on the plains of southern Serengeti (Dietrich, '42). Besides ancestors of the African elephant, *Archidiskodon exoptatus* Dietrich, there existed *Sivatherium*, *Dinotherium*, Chalicotheridae (*Metaschizotherium*) and three-toed horses (*Hypsohipparion*). The important part of this fauna belongs to the oldest Pleistocene or to the Plio-Pleistocene boundary. Very important are some fragments of a hominid to whom was given provisionally the name *Meganthropus africanus* Weinert.

The fragments are (1) a third molar of the right maxilla (M^3) and (2) the two premolars of the left maxilla (P^3 and P^4), in a beautiful state of preservation. These premolars are in situ in a fragment of the maxillary bone, which still shows the alveolus of the canine tooth.

The third molar is similar in structure to the corresponding teeth of *Sinanthropus*, but it is somewhat bigger (buccolingual diameter 13 mm, mesiodistal diameter 10.1). The metaconid is small, the roots are short and coalesced at the base.

The premolars are more important. Premolars have often been taken to indicate a pronounced difference between Hominidae and Pongidae. The Pongidae were said to have very different premolars, i.e., a heteromorphic canine group. On the contrary the premolars of the Hominidae are similar to one another; the canine group is homomorphic. These differences really exist and they have often been used to deny the possibility of deriving the Hominidae from Pongidae, the Pongidae being too specialized in this respect (cf. Adloff). This conclusion was not accepted by Gregory ('26, '52) and Remane ('27). These authors pointed to the small but distinct differences between the first and second premolars of the Hominidae,

which resemble those found in the Pongidae. The premolars of *Meganthropus africanus* now are obviously intermediate between those of the Pongidae and those of the other Hominidae. The P^3 has three roots, as have the Pongidae in the most cases, but this is very exceptional in the Hominidae. The roots of P^4 are, as far as may be recognized, intermediate between two roots and three roots. The antero-interior extension of the buccal surface is more evident than in the premolar of any known other hominid, and the differences between P^3 and P^4 are also more evident than in the other Hominidae. The

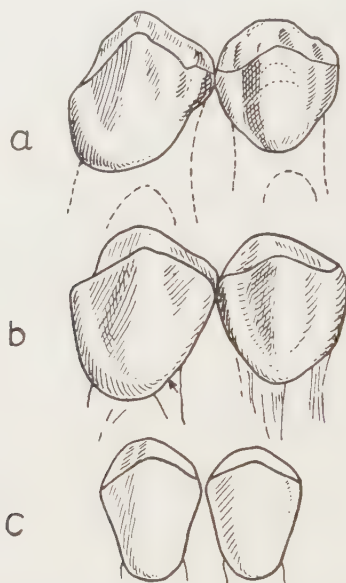


Fig. 1 The upper premolars P^3 and P^4 . (a.) of *Dryopithecus punjabicus* after Pilgrim; (b.) of *Meganthropus africanus*; (c.) of recent European, oblique view from buccal side.

placing of *Meganthropus africanus* in the Hominidae is demonstrated by the crests and ridges of the enamel, the lowered point of the principal cusp and the alveolus of the canine, which demonstrates the existence of a smaller canine than in the Pongidae.

The premolars are very big. The dimensions are: P^3 mesiodistal 9.6 mm, buccolingual 12.3; P^4 mesiodistal 9.1 mm, buccolingual 12.5 mm.

Meganthropus africanus is a very primitive hominid, who in structure of the premolars is nearer to the pongids than is any other hominid known till now. The determination of the relationship to

the other Hominidae of the Pleistocene is difficult. The resemblances with the South African hominids *Plesianthropus*, *Australopithecus* and *Paranthropus* are not very distinct. The number of roots of the premolars is also higher on average in these fossil Hominidae than

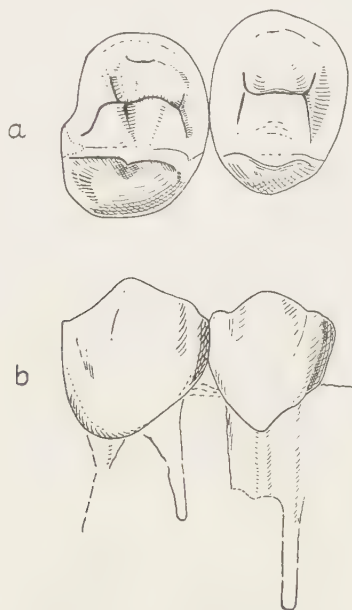


Fig. 2 The upper right premolar of *Meganthropus africanus*. (a.) occlusal view; (b.) buccal view. Natural size.

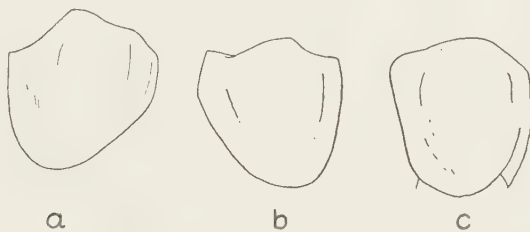


Fig. 3 P^3 of (a.) *Meganthropus africanus*; (b.) *Plesianthropus* after Robinson; (c.) *Paranthropus* after Broom. Natural size.

in the recent man, but the antero-exterior extension is not marked and the premolars are molarized, and so in respect to this different from Pongidae and the other Hominidae. Robinson's newly published paper ('53) gives a detailed description of the P^3 of *Plesianthropus* and comes to the conclusion that this tooth is very near to that of

Meganthropus africanus (fig. 3). But there is no antero-exterior extension of the buccal surface in *Plesianthropus*; the main cusp is lower. I doubt whether the more pongid premolars of *Meganthropus africanus* are the same species as *Plesianthropus*. Robinson also includes *Meganthropus palaeojavanicus* in the Australopithecinae. The genus *Meganthropus* was based on a fossil hominid from Java (*Meganthropus palaeojavanicus* von Koenigswald), and the African "*Meganthropus*" resembles this form in the structure and dimensions of the premolars — but only the lower premolars are known in *M. palaeojavanicus*, not those of the maxilla, which are only known in *M. africanus*. The bones of *M. palaeojavanicus* are extraordinarily massive and this character is not to be found in *M. africanus*. Hooijer has discussed the possibility of identifying *Meganthropus palaeojavanicus* as a male of *Pithecanthropus robustus* = *modjokertensis*. That is quite possible in view of the greater sexual dimorphism which evidently existed in the Pleistocene Hominidae as in other Pleistocene mammals. In this case a close relationship of the Javanese and African *Meganthropus* would be possible. *Meganthropus africanus* seems to represent an older stage of the Hominidae in a morphological sense than the other Pleistocene hominids of South Africa. There are needed further remains of this interesting form before its exact position may be determined.

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THE MEASUREMENT OF SKIN TEMPERATURE

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Of the various measurable properties of the human body not requiring elaborate apparatus or chemical analysis, skin temperature seems to have been ignored by physical anthropologists. No mention of skin temperature is made in standard texts, no article on skin temperature measurement has appeared in this journal since the new series was instituted, and of the 12,000 citations in Krogman's *Bibliography of Human Morphology* ('41) only one refers specifically to the measurement of skin temperature. Yet skin temperature is not difficult to measure, apparatus suitable for laboratory or field use is commercially available, and there are a number of reasons for adding skin temperature to the list of measurements. Skin temperature apparently affects basal oxygen consumption, there appear to be racial differences in basal skin temperature, and under solar radiation skins of different color heat up differently. Reference should be made to Lewis ('24) and his pioneering application of dermal thermometry to the study of vascular problems, and to the detailed review prepared by Sheard ('47).

Obviously, it is not practical to measure skin temperature by attaching a clinical thermometer to the body surface, nor are commercial surface thermometers accurate enough or sensitive enough for the purpose. However, there are at least 4 thermometric techniques that have proved satisfactory with ranges of accuracy from 0.01°C. to 0.5°C. The anthropological investigator may choose among thermocouples, thermistors, wire-type resistance thermometers and radiometers. All 4 techniques, which are fully described by Prouty and Hardy ('50), are suitable for laboratory purposes, and in general for field work as well.

Thermocouples (couples of dissimilar metals) possess one major advantage. They actually generate a current, the current is proportional to the temperature, and the current is sufficient to actuate a sensitive galvanometer without amplification. Thus batteries, amplifiers and other equipment subject to deterioration or "drift" may be dispensed with. Ordinarily, in addition to the galvanometer and the "test junction," a second "reference junction" is wired in series. This second thermocouple, maintained at a known temperature (usually that of an ice-water bath) makes possible the measurement

¹ The assistance of G. Daniels and F. Van Wart in building various types of thermocouples is acknowledged, as is the aid of L. C. Clark, Jr. and Fred Hooven in the preparation of this short review.

of absolute as well as relative skin temperatures. Formerly the Rubicon Co., Philadelphia 32, Pa., manufactured a complete thermocouple-type skin temperature meter. At present (August, 1953) they offer only the galvanometer unit, though they will supply information on the most suitable thermocouple wire. The Leeds and Northrup Co. also manufactures potentiometers for use with thermocouples.

In contrast to thermocouples, which indicate skin temperature by the magnitude of the current generated, thermistors change their resistance with changes in temperature. In using a thermistor, resistance is measured with an ohm-meter, which if suitably calibrated against a precision thermometer, can be made to indicate skin temperature directly. Thermistors can be purchased, on special order, from the General Electric Corp. However the Yellow Springs Instrument Co., Yellow Springs, Ohio, has recently developed an inexpensive thermistor-type skin temperature meter, ready calibrated for the usual range of skin temperatures. This device, accurate to a fraction of a degree, will operate over 2500 hours on a single dry cell.²

Resistance thermometers, like thermistors, vary in resistance according to temperature, and thus indicate temperature on a pre-calibrated ohm-meter. In the temperature range 70° to 100°F., a short length of 1 mil. wire, wound into a spiral or helix, makes a suitable test unit for skin temperature determinations. Formerly Trans-Sonics, Inc., Bedford Airport, Mass., manufactured a small plastic-encased resistance thermometer unit for this purpose. At present no source of ready-wound units is known to the author. One mil. wire suitable for the purpose may be purchased from Eberbach Co., Ann Arbor, Michigan.

Finally one should mention dermal radiometers, such as the Hardy-type instrument manufactured by Baird Associates, Cambridge, Mass. Strictly speaking dermal thermometers do not measure skin temperature, but rather measure the radiation from the skin surface, radiation primarily in the infrared. Actually the relationship between temperature (as measured) and radiation is high. Dermal radiometers do not need to contact the skin—they may be aimed at it. This is an advantage, and at the same time a disadvantage for specificity of measurement is thus lost, and the relatively large size of the thermally-sensitive detector precludes certain types of operations.³

² At the request of the author the Yellow Springs Instrument Company has engineered a special model of this device with 6 leads. This multi-channel instrument permits the simultaneous measurement of skin temperatures on 6 selected points of the body or alternatively on 6 subjects at once.

³ The Baird Dermal Radiometer has the greatest sensitivity and the greatest accuracy of any of the instruments described, being capable of recording changes in skin temperature as small as .01°C.

Thermocouples, thermistors or resistance thermometers, in contrast, may be attached to the subject (or in some applications sewn into his clothing), while the measuring unit (potentiometer, or ohm-meter) may be located at a distance, depending upon the length of the connecting wires. Thus in environmental protection studies, test subjects are subjected to heat or cold, while the actual temperature values are read in comparative comfort. In the investigation of solar radiation effects the test subject may be placed in direct sunlight, while the investigator rests in the shade. Similarly a portion of the subject may be refrigerated or heated, and the temperature of the test portion, compared to the oral temperature or that of adjacent skin areas. Also it is possible to maintain a constant watch on the skin temperature of exercising or sleeping subjects when these techniques of dermal thermometry are used.

It may be noted that accurate, reproducible skin temperature measurements depend upon close contact between the skin surface and the thermocouple or other measuring unit. A slight separation (1 mm) or insufficient contact may lead to an error of $\pm 2^{\circ}\text{F}$. This problem is the same whether thermocouples, resistance thermometers, or thermistors are used; it does not exist with dermal radiometers. For some purposes, such an error is of no import. For other uses it defeats the purpose of the study. Thus small and responsive thermocouples may be less satisfactory than less responsive units backed by a small silver button. Where subjects are exercising, or where it is inconvenient to maintain contact manually, the problem of good thermal contact warrants careful attention.

Though it is not practical to review the range of problems involving skin temperature measurements, a few areas of interest may be noted. There is evidence that dark skins heat up more rapidly under solar radiation, or when illuminated by shorter wavelengths (Buettner, '53). This does not mean that dark skins lose heat more rapidly, for in the infrared a white skin is nearly a perfect "black body." Skin temperature appears to be lower after tropical acclimatization, thus explaining the lower basal oxygen consumptions noted among equatorial peoples. On the other hand, Brown and Page ('52) and Brown et al. ('52) have cited evidence to show that the Eskimo has a higher peripheral skin temperature, a possible explanation for his increased basal metabolic activity, and his greater resistance to cold. These investigations show that the addition of skin temperature measurements to our regular list may contribute both to the "body of data," and to the list of adaptive traits that we are slowly compiling. Obviously if it is possible to demonstrate real inherited adaptations to either tropical or arctic conditions, physical anthropology will be that much ahead.

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INTERNATIONAL OPINION ON RACE.—Scientists have reached general agreement in recognizing that mankind is one: that all men belong to the same species, *Homo sapiens*. It is further generally agreed among scientists that all men are probably derived from the same common stock; and that such differences as exist between different groups of mankind are due to the operation of evolutionary factors of differentiation such as isolation, the drift and random fixation of the material particles which control heredity (the genes), changes in the structure of these particles, hybridization, and natural selection. In these ways groups have arisen of varying stability and degree of differentiation which have been classified in different ways for different purposes.

From the biological standpoint, the species *Homo sapiens* is made up of a number of populations, each one of which differs from the others in the frequency of one or more genes. Such genes, responsible for the hereditary differences between men, are always few when compared to the whole genetic constitution of man and to the vast number of genes common to all human beings regardless of the population to which they belong. This means that the likenesses among men are far greater than their differences.

REVIEWS

AN INTRODUCTION TO ANTHROPOLOGY. By Ralph L. Beals and Harry Hoijer. xxi + 658 pp.; 10 maps; 12 charts; 110 figs. Macmillan Company, New York. 1953. \$6.00.

Perhaps the greatest challenge to the anthropologist is the writing of an introductory textbook. In a field where every aspect is undergoing modification and reinterpretation, and where problems far outnumber solutions, and laws and principles are hard to come by, only the bold untrammelled soul dares attempt to gather up all the pieces and fit them into a nice picture that freshmen and sophomores can view with comprehension. Perhaps it is too much to expect, with the present status of anthropological studies, a book that is at once a "text" and an "introduction."

Beals' and Hoijer's book, with respect solely to the section (pages 20-203) on physical anthropology, comes little closer to meeting this challenge than any of the other recent attempts. In treating their major theme — "the origin, development, and differentiation of man as a biological organism" — they claim to have emphasized "as far as possible" the newer genetic approach. In the process this approach rapidly takes on the hues of the classic heredity school of 1920-1930.

It is stated that the two themes — man as a biological organism, and the concept of culture — may not be separated if the latter is to be properly understood; yet there is little real attempt at integration. There is nowhere a discussion of physical growth and development of the human organism although a whole chapter (19) is devoted to the Education and Formation of Personality. Nor can the complete omission of the field of constitution be excused, particularly when the authors themselves raise the question: "Is there any relationship between man's physical type and his temperament, intelligence, special aptitudes, or behavior in general?"

The opening chapter, *Man and the Animals*, deals with taxonomy, comparative morphology, embryology, and evolution. Yet there is no mention of the basic principles of evolution — adaptive radiation, parallelism, rates of evolution, convergence, extinction, etc. That these principles are nowhere to be found in this text constitutes, in the reviewer's mind, its single most serious deficiency. It has led the authors to numerous errors of fact and judgment, and will misinform the student. Certainly we cannot agree that "one or two

notions," once defined, will clear the way to an understanding of human evolution; particularly, when these "notions" are those of specialization vs. generalization, presented with the classical Darwinian stamp.

What genetic concept of evolution has led the authors to point out that "the precise connecting animal (or 'missing link') is lacking . . ." between ape and man? Shouldn't the emphasis rather be on the evolutionary stages, which are becoming better known and on which our techniques are better adapted for giving us reliable information?

Four-fifths of the chapter on Heredity and Genetics is devoted to an exposition of Mendelian genetics while only a page or two is allowed for such subjects as mutation, genetic drift, isolation mechanisms and effects, the concept of breeding populations, and natural selection. Surely the student is entitled also to the new understandings of what genes are and how they act — physiological genetics.

We wonder if the statement that the number of albinos "could no doubt be reduced if albinos were not permitted to reproduce themselves" is meaningful enough to risk giving the student a false concept of the effectiveness of eugenic measures at the present time. We fail to reconcile the position maintained when the authors assert that the American Negro is becoming a "stabilized mixture of race" with their subsequent statement that "races can only be more or less temporary assemblages of genes and gene complexes." The expediency of their treatment is revealed in another passage: ". . . races may in some sense be considered as more or less stabilized patterns of genes. . . ." On what basis do the authors predict that the "American Negro group will probably gradually modify toward the white type (sic!)"?

The chapter called *The Criteria of Race*, while generally of a higher caliber than the preceding, deals only cursorily with the ABO blood groups and fails to mention other genetically known blood antigens. The authors have leaned heavily upon Hooton and Coon in their chapter on *Racial Types among Modern Men*. But here again they run into difficulties stemming from their half-hearted attempt to apply the genetic approach. Although they have stressed earlier the temporary nature of races they find no inconsistency in tracing some of these races back to Pleistocene times!

A basic weakness in the chapter on *Fossil Man and Racial History* is the failure to come to grips with the species concept in the light of the "newer genetic approach." This has led the authors to an uncritical assigning of various scraps of fossil hominids to variable specific or generic ranking on the one hand; and to the glib acceptance of interbreeding between species and genera as an explanation of

morphological intermediacy. Are the morphological tools of the physical anthropologist so sharp as to permit the statement: "*Modjokertensis* appears to belong to the genus *Pithecanthropus*, though possibly not to the same species as *Pithecanthropus erectus*"? The apparent unawareness of the authors of the principles of evolution has led them to speak of "asymmetrical evolution" as if this concept has any real meaning or validity.

In any new text we justly expect a fairly comprehensive coverage of the recent South African finds of Australopithecinae. These profoundly affect modern interpretations of human evolution. Yet Beals and Hoijer refer only to the original three type specimens.

The final chapter of the physical section is entitled Race Problems, and is probably the best of the lot. Even here, however, the authors run into difficulties in their discussion of the hereditary nature of intelligence.

The reviewer has dealt solely with some of the inadequacies of this volume. There are, however, many good points. Perhaps he can best sum up by saying that the book is "introductory" but is not a "text." It deserves a trial on the basis of the fact that it opens the door for a lot of classroom discussion and leaves the instructor with something to teach.

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INTRODUCTION TO EVOLUTION. By Paul Amos Moody. xii + 475 pp.; 153 figs.; 3 tables. Harper & Brothers, New York. 1953. \$6.00.

The renewed interest in organic evolution, largely associated with the modern synthetic theory, has created a real need for an up-to-date and well organized elementary textbook covering all the major aspects of this fundamental biological generalization. Within the last few years this want has been partly satisfied by three new texts: Carter's "Animal Evolution" (London, 1951), Dodson's "A textbook of evolution" (Philadelphia and London, 1952), and Lindsey's "Principles of Organic Evolution" (St. Louis, 1952). The first is probably too advanced to be generally acceptable as an undergraduate, introductory text, while the other two are clearly biased in their theoretical considerations.

The subject of this review, written by the Howard Professor of Natural History and Zoology at the University of Vermont, is, in this writer's opinion, the best elementary textbook on evolution now available. Although concerned almost exclusively with animal evo-

lution, the role that plants have played in developing modern evolutionary theory is briefly considered, including mention of polyploidy. The historical background of the synthetic theory is not outlined, but historical developments are discussed at many places in the text.

Following two introductory chapters, one of which deals briefly with the dawn of the evolution idea and the other with some major factors in evolutionary change, 12 chapters are devoted to the factual basis of evolution. The evidence derived from invertebrate and vertebrate morphology, comparative embryology, biochemistry and physiology, comparative serology, as well as geology and the fossil record is carefully reviewed. There is perhaps some danger that the student may lose track of the central theme by becoming too involved in all the factual minutiae, although the author does employ this mass of evidence in the usual manner to illustrate homology, parallelism, adaptation, adaptive radiation, etc. One minor criticism might be mentioned here to stress the need for careful explanation, particularly at the textbook level. In discussing the origin of the Cetacea, the author points out that there is a close serological relationship between this order and the Artiodactyla. Both orders probably arose during the Paleocene. Although the cetacean ancestry is unknown, the transition from primitive ungulates (condylarths) to artiodactyls is unusually well documented. The meaning of the cetacean-artiodactyl serological relationship may never be entirely clear. Serological tests unfortunately cannot be made on the extinct condylarths, representing the ancestral stock of the artiodactyls, or on the extinct creodonts, usually regarded as the ancestors of the whales.

The chapter on the evolution of man is an unprejudiced and on the whole enlightened attempt to explain human phylogeny in terms of modern systematics and evolutionary theory. Following the lead of Dobzhansky and Mayr, three species of *Homo* are recognized: *H. transvaalensis* for the australopithecines, *H. erectus* for Java and Pekin, and *H. sapiens* for all the others including Neanderthal. The author states that this is "a serious pioneer attempt to bring human classification into line with the classification of lower animals."

The sections on the geographic distribution of animals perhaps suffer from too much fact in proportion to generalization. For instance, Simpson's illuminating concept of faunal stratification, which must apply to all land organisms, is not mentioned. Centers of dispersal are not "abundantly realized" (p. 248) from the evidence of the fossil record; they may be postulated for only a few orders of mammals.

The mechanics of evolutionary change are considered in 4 chapters at the end of the book. In spite of the seeming condensation, Professor Moody has discussed most of the important aspects of this

many-faceted subject lucidly and in logical sequence. Worthy of particular notice are the sections on the significance of the Hardy-Weinberg formula and on allometry. Several summaries (pp. 374-377; 409-412) will assist the student in obtaining a broad synthetic picture of the entire process.

The final chapter, entitled "What of it? An Open Letter to Students," considers the religious and social implications of organic evolution. Frankly and carefully written, it covers topics of considerable interest and concern to many undergraduates — topics which are unfortunately rarely discussed in the classroom.

Professor Moody's book may be heartily recommended as a beginning text on organic evolution. Although the organization is rather formal, and the subject matter perhaps excessively subdivided, the presentation is uniformly clear and easy for the student to follow. A scale designation would enhance the value of many of the illustrations. The index appears entirely adequate.

BOBB SCHAEFFER

American Museum of Natural History

THE LIFE OF VERTEBRATES. By J. Z. Young. xvi + 767pp; 497 figs. Oxford, at the Clarendon Press. 1950. \$8.50.

By coincidence, two valuable new books of comparative zoology have been given us almost simultaneously. Romer's *The Vertebrate Body* is more definitely a treatise of comparative anatomy, although, as one would expect from the author's wide interests and the scope of his previous books, the material is well integrated with cytological and embryological concepts, and of course the paleontological side of the subject is particularly well developed. The organization of the book is by organ systems. J. Z. Young, on the other hand, has undertaken to treat the entire *Life of Vertebrates* in a "combined account of the embryology, anatomy, physiology, biochemistry, palaeontology, and ecology of all vertebrates." The great merit of such a work is that it brings together all aspects of an animal's structure and function and adaptive relations to its environment; the difficulty of the task lies in the very abundance and diversity of the material to be so unified, and the consequent difficulty in adhering to a comparative point of view, or even of keeping a suitable balance between different aspects of the life of vertebrates. Perhaps no man could have done better, although Young willingly acknowledges his deficiencies when it comes to discussing such matters as the evolution of chemical and energy interchanges.

The very size of the undertaking has made it necessary to limit the present book to a more general treatment of the mammals in comparison with the other vertebrate classes, and a second volume is to be devoted to a more detailed treatment of mammalian organization — structure, function, and development. Comparative embryology has also been left almost entirely to the second volume. What remains is still a vast panorama of vertebrate life, and no reader will fail to find this work a mine of valuable and interesting details unknown to him. The chapters on the lampreys, the elasmobranchs, and the bony fishes are particularly good, having been enriched by the author's own investigations of their anatomy and physiology, along with his comprehensive knowledge of the contributions to an understanding of their anatomy made by E. S. Goodrich and his students. The inclusion of an entire chapter on Bird Behaviour is a novel feature, and allows the recent studies of Tinbergen, Lack, Huxley, Stresemann, and others to throw valuable light on the more conventional treatment of avian anatomy, physiology, and evolution. (It is regrettable that the work of Lorenz was not made use of.) Lack's investigations of the adaptive radiation of the Geospizidae of the Galapagos Islands are used extensively in considering the evolution of birds, and no doubt the equally remarkable facts about the Hawaiian drepanids studied by Amadon would have been used had they been published in time.

Coming to the section on the mammals, one finds chapters on the Origins of Mammals and the Evolution of Placental Mammals, together with 11 chapters devoted to the important orders or groups of orders. Among these, a chapter on the Primates and another on Monkeys, Apes, and Men will particularly interest the physical anthropologist. In all these chapters the general systematics of the groups, their skeletal anatomy, and some consideration of their adaptations are supplemented by occasional excursions into such topics as population fluctuations among the rodents; but treatment of the evolutionary aspects seems unsatisfactory because of the curtailment of the paleontological material. One would suppose, for example, that Tilly Edinger's remarkable delineation of the course of evolution of the brain in the horses would have been discussed. Its implication of extensive parallel evolution among mammals in mental capacity could have been used to strengthen the generally excellent summary of evolutionary changes in the life of vertebrates which comprises the last chapter of the book.

In any compilation and synthesis so vast as this, errors of detail are to some degree unavoidable. These seem to be remarkably few and inconsequential. A good subject index and a compilation of general references arranged by chapters completes the text. A word of com-

mendation is also due to Miss E. R. Turlington, who has executed most of the admirably clear and frequently artistic original illustrations. The total of 497 line drawings amounts to almost one per page, a fact that sufficiently indicates the wealth of illustration provided.

All readers who are interested in the place of man among the vertebrates and who wish to see him in a full and rich background of anatomical, physiological, and ecological relationships will need to consult this book. Those who do so will eagerly await the publication of the second volume, and without question will want to add both to their personal libraries.

BENTLEY GLASS

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ARCHEOLOGY AND RACE IN THE AMERICAN INDIAN. By Georg K. Neumann. A chapter (pp. 13-34 and figs. 1-9) in "Archeology of Eastern United States" edited by James B. Griffin and dedicated to Fay-Cooper Cole. The University of Chicago Press, x + 392 pp. and 205 figs. 1952.

Over the years investigations of the skeletal remains of North American Indians have yielded more or less definite concepts of types or varieties with localized distributions. Hrdlička spoke rather vaguely of Algonkin, Gulf, Siouan and other types. Von Eickstedt in 1934 (followed closely by Imbelloni) formalized such information in a comprehensive racial classification that assigned 5 types with other names to definite parts of North America. But no one, until now, has systematically re-examined from this point of view the original specimens and connected them with the available archeological information in order to reconstruct the racial history of the continent. For the last 20 years, Neumann has been painstakingly viewing and measuring Indian skulls — 10,000 of them — as well as visiting the more important archeological sites. The present work, being Neumann's first extensive publication based on this impressive experience, thus merits respectful consideration.

Actually, this publication is a reduced version of a doctoral dissertation at the University of Chicago, which bears the title "Racial differentiation in the American Indian" (procurable from the library of the University in microfilm — no. T770). The published version omits, unfortunately, the basic tables of measurements, but retains 5 plates of photographs of living Indians which have little bearing on the subject. Therefore, in fairness, the reviewers have consulted both versions.

It should be kept in mind that Neumann is dealing with very real problems in historical physical anthropology. Whenever skeletal remains are recovered in an archeological setting, questions arise regarding physical relationships, and particularly whether they point in the same directions as the cultural indications. The search for answers requires skeletal descriptions and comparisons, which by themselves are somewhat routine, but almost inevitably, it would seem, lead to concepts of types or varieties. (The two terms probably mean the same thing. Neumann uses "variety" in the sense of biological taxonomy; that is, somewhere between a subspecies and a local strain.) A fuller exploration of the concept and whatever meaning lies behind it is thus a legitimate project.

We emphasize this point because we are aware that any scientific study which has been in progress for 20 years is apt to emerge in an atmosphere of ideas quite different from that surrounding its inception. Such is true in the present case. Skeletal studies have tapered off in the last 20 years and the emphasis in physical anthropology in general has shifted away from anthropometry as a result of experimental studies on bone growth, advances in population genetics and revived interest in the effect of environment on physique. As yet, however, these newer studies offer little to supplant craniology as a means for investigating man's spread into and expansion on this continent. Needless to say, Neumann's new classificatory scheme will find wide acceptance only if it reconciles all pertinent knowledge and serves as a useful tool in making further advances.

With this introduction we will proceed to state what in our opinion are the main assumptions used by Neumann in dividing the North American Indians into varieties and in interpreting their significance:

1. That "the peopling of the New World was not the result of a single wave of people, but rather a continuing series of migrations lasting from perhaps immediately post-glacial times to around the beginning of the Christian Era" (p. 13).
2. That "the earlier immigrants were . . . pushed into refuge areas and the less accessible margins of the continent, while those that arrived later settled more centrally located areas" (p. 14).
3. That "the appearance of new varieties in an area can be checked by stratigraphic and typological evidence from archeology" (p. 14).
4. That a variety, being "a zoological group of a certain order of differentiation characterized by the possession of a combination of a selected number of inherited morphological attributes" (p. 14), it follows that such a group "must have formed an inbreeding community" (p. 14).
5. That "the formation of new varieties takes place constantly in nature" (p. 14) and that "on the other hand, mixture, with recombination of traits, may give rise to secondary varieties" (p. 14).
6. That morphological resemblance between homogeneous small series from "a given archeological horizon and usually a fairly circumscribed area" identifies survivors of the same ancestral population.

Although the first three assumptions have become time honored, they account for the varieties primarily through heredity, and a restricted form of heredity at that. Environmental influences are barely mentioned. The last three assumptions, on the other hand, give subjectivity a large role. Neumann has had to judge the homogeneity of his series (the method is not explained) and decide which differed sufficiently in "morphological attributes" to warrant being designated as varieties.

Be this as it may, the following are the varieties arrived at in this way:

1. *Otamid* (Papago: *O'otam*, "people"): Defined by a series of 18 male skulls from the Texas coast.

2. *Iswanid* (Catawba: *Iswa*, "river," and *nie*, "people"): Defined by a series of 33 male skulls from Indian Knoll, Kentucky.

3. *Ashiwid* (Zuni: *A'shiwi*, "the flesh"): Defined by a series of 15 male Basket-Maker skulls from Arizona.

4. *Walcolid* (Muskogee: *Wahali*, "south;" *cola*, "people"): Defined by 45 male skulls from Central Illinois (Spoon River Focus).

5. *Lenapid* (Delaware: *Lenape*, "real men"): Defined by 24 male skulls from Central Illinois (Maples Mills Focus).

6. *Inuid* (Eskimoan: *Inuit*, "men"): Defined by Morant's Greenland series of 241 males.

7. *Deneid* (Athabaskan: *Ti'ine*, "people"): Defined by a pooled series of 32 male skulls from several tribes.

8. *Lakotid* (Teton Dakota: *Lakota*, "allies"): Defined by 63 skulls from various Dakota bands. A secondary variety.

These 8 varieties with their new names bear little resemblance to the types of Hrdlička or von Eickstedt. Where Hrdlička's concept of an Algonkin type, for example, was so vague as to encompass such scattered groups as Algonkians, Iroquois, bearers of the "Archaic" culture in Kentucky (Indian Knoll) and Basket-Makers, Neumann substitutes at least 4 varieties: Otamid, Iswanid, Ashiwid and Lenapid. And where von Eickstedt gave each of his types rather exact geographic boundaries, Neumann suggests distributions mainly through mention of sites and tribes. Thus, although it might be questioned whether the refinement of types or varieties has now been carried too far, it can hardly be claimed that their distribution has now been oversimplified.

Neumann's classification differs from those of his predecessors also in its utilization of archeological data to give time depth. By this means he reaches the conclusion that "the older varieties, such as the Otamids, Iswanids, and Ashiwids, almost certainly can be traced back far beyond [2,000 B.C.], although the series [upon which they are based] may be relatively recent" (p. 15).

Among many other such conclusions, the following may be cited to show the nature of the historical reconstructions:

The Otamid variety "is practically the only one that is encountered archeologically during the time the Early Woodland culture flourished from Nebraska east to the Atlantic seaboard" (p. 17). The Ashiuid and Iswanid varieties, of the Southwest and Southeast, respectively, "had an immediate common ancestry [and] a split must therefore have occurred somewhere in the plains area" (p. 19) with subsequent differentiation. "The Walcolid variety is usually associated with material from late archeological horizons. . . . As a whole, the distribution . . . suggests a variety whose former continuous distribution was shattered by later immigrants" (p. 22). "In all probability a number of migrations took the Lenapids east" (p. 24) where they are "most closely linked on the cultural side with the Central Algonkian tribes" (p. 25). "The earliest Deneids . . . were in all probability very much like the . . . Proto-Aleut. . . . It is fairly safe to assume that these tribes were Athabaskan speakers. . . . In their migrations southward, probably after 1300, some of the Deneids wandered to California . . . others reached the Southwest . . ." (p. 29). "The Lakotid variety is a secondary one in the sense that it probably represents the results of hybridization of 2 or 3 other varieties" (p. 29) — Deneid, Lenapid, Otamid.

Since these interesting and helpful reconstructions have been compounded from the findings of archeology and craniology and we are concerned here mostly with the way the latter have been used, we will limit our remaining comments to the selection of the varieties. Naturally, any weaknesses found in the varieties will apply also to the reconstructions based thereon.

The earlier mention of the role of subjectivity in the development of the varieties can be shown most strikingly in two sets of cranial comparisons: (1) Texas Coast vs. Manhattan-Long Island (mainly the work of Charles E. Clauser) and (2) Arizona Basket-Makers vs. Indian Knoll. In each case 6 of the 17 measurements and 5 of the 8 indices show statistically significant differences. The differences in the non-metrical traits are not so easily summarized, but seem to be somewhat greater in the Basket-Maker: Indian Knoll comparison. Nevertheless, Neumann sees only one variety — Otamid — in the Texas Coast and New York series, whereas he sees different varieties — Ashiuid and Iswanid, respectively — in the other two series. In view of the small morphological differences involved, the number of varieties decided upon seems rather arbitrary. Apparently here the archeological evidence outweighed whatever objectivity resides in craniometry. Had these series been archeologically undocumented, Neumann might have decided differently.

Neumann also fails to recognize one of the faults of craniometry currently under criticism, namely, the giving of equal weight to

measurements and observations that repeat a single feature. Thus, two of the 6 significantly different measurements between the Basket-Maker and Indian Knoll series — total facial breadth and biangular breadth — reflect the greater facial breadth of the latter group. This same feature appears again in the most striking non-metrical characteristics of the Indian Knoll series, which here take the form of greater lateral projection of the zygomata and more pronounced eversion of the gonial angles. If, then, a good part of the difference between the series upon which the Ashiuid and Iswanid varieties are founded is due to a factor for face breadth, it seems likely that size of sample may enter the picture. As a matter of fact, Hrdlička's Utah Basket-Makers exceed those from Arizona in average face breadth by 2.4 mm. Such evidence leads us to conclude again that these particular varieties have more archeological than craniological validity.

We are more willing to accept the other varieties (their interpretation is another thing), although here also their definitions are overly restrictive, expressed as they are in terms of the means and modes of small series. Neumann's own admission (p. 14) that up to 70% of a series representing a variety may not fit the definition suggests that the definitions themselves need expansion. As they stand, given a single specimen or a small series from an archeological site for interpretation, one is hardly better off than before in placing them within a systematic structure. Moreover, non-metrical observations cannot be readily compared because Neumann has not published his standards.

It is easy to go on in such a fashion criticizing this work, and in so doing one is tempted to brandish phrases made popular by the sciences of ecology and population genetics. Whether or not more could be learned from such material by genetic analysis remains to be proved. Perhaps it is too early to try, and in any case genetic analysis would likely involve the assembling of much the same data in a somewhat different form. Had Neumann been able to conclude his efforts in half the time, and document them more elaborately, he would have been applauded from all sides. As it is, probably only the few now working with cranial material — and the archeologists — are really impressed by the interpretative sweep and grateful for the research leads.

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EUGENICS: GALTON AND AFTER. By C. P. Blacker. Harvard University Press, Cambridge, Massachusetts. 1952. 349 pp. \$5.00.

PREFACE TO EUGENICS. By Frederick Osborn. Revised Edition. Harper & Brothers, New York. 1951. xiv + 333 pp. \$4.00.

It is now just 70 years since, in his *Inquiries into Human Faculty*, Francis Galton first coined the word "eugenics" to describe a program of human betterment which was to comprise not only a program of scientific investigation but also — and perhaps of greater importance — a plan of social action. Since that time the arguments have raged over this new field; and criticisms have been directed not so much against the *ideal* of population improvement as against the scientific bases which might underlie the specific plans and policies.

The two books under review have been written by contemporary exponents of eugenics. Both authors are intellectual descendants of Galton, sharing his temperateness, his reason and his ideal. But they also share his biases which, acceptable as they were during Galton's lifetime, read strange in the somewhat different temper of these times.

The pedestrian and non-critical biography which comprises the first half of Blacker's book, provides a swiftly drawn outline of the philosophical and social matrix from which eugenics was born. Galton, a first cousin of Darwin, drank fully of the cup of optimism which pervaded the atmosphere of science and scientist during the latter half of the nineteenth century, that period of the Victorian climax in England equalled in its self-confidence and vanity only by the period of the French savants a century earlier. To Galton, as to his intimates in the exclusive "X Club" and their disciples, the success of Darwin's evolutionism, coupled with the tremendous technological developments of their time, presaged an age of scientific rationalism and order without parallel in the history of man; they saw a social revolution which would inevitably — and quickly — lead to a society in which the scientist would be both director and manager of a benevolently paternalistic state, a society whose goals and the methods for their achievement could be constructed upon verifiable principles derived from scientific law.

Events in the twentieth century, both social and scientific, have tempered that optimistic outlook as they have tempered the earlier and more naive hopes of the eugenicists. More and more eugenics has become a point of departure for inter-disciplinary research designed to understand better the complex forces which produce man in his infinite and subtle variety. The two books under review, the latter more than the former, serve as convenient — and sometimes overlapping — compilations of the data bearing upon the nature of human variation; for, as both Blacker and Osborn recognize, it is

upon an understanding of this phenomenon that any program for eugenic selection must rest. This material (sometimes presented too positively as in the case of Osborn's discussion of mental illness and deficiency) from genetics, psychology and population research is undoubtedly familiar to most anthropologists and needs no further review here. The extremely difficult, and yet important, sociological problem of "value," however, is given no adequate recognition.

Running through both books, as one might expect from friendly witnesses, is the eugenic theme: the necessity of translating the "science" into "social action" in the face of demographic phenomena which the authors view, in the framework of their culture, with some alarm. Eschewing compulsory measures (cf. Blacker, p. 232 and Osborn, p. 320), whose abuses under the Nazi eugenics program are still too vivid in the memory of man, the contemporary eugenicist argues only for a program so slow and careful as to be a faint shadow of Galton's dream. Nevertheless one might argue even with so temperate a proposal. Recognizing the significant role of arbitrarily constructed values in establishing selective criteria, the relation of population change to population size, and the ephemeral nature of "adaptive" characters, it might seem that a more practicable approach to the self-same problems of rapidly increasing population would be the recognition of the population as it is and the construction of more malleable socio-cultural programs to fit that reality.

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PHYSIOLOGY OF EXERCISE. By Lawrence E. Morehouse and Augustus T. Miller. Second Edition. C. V. Mosby Co., St. Louis. 355 pp. \$4.75. 1953.—Now in its second edition, this has become the authoritative text in the field. Written by two former members of the Harvard Fatigue Laboratory, it is adapted to readers who are not physiologists. Beginning with 4 chapters on muscle (including muscle metabolism) the various effects of exercise are considered, as are the conditions for optimum muscular effort. The final two chapters, one on age, sex, body type, and race (in relation to exercise), and the other on environmental temperature, may prove of special interest to physical anthropologists. There is an 8-page glossary and a 14-page index.

Though this book may be taken up initially to acquire knowledge on a specific subject, for example, physical fitness tests (chapter 23), or to locate references; the variety of interesting information it contains encourages browsing. There are many tantalizing statements, of which a few may be cited. "The human body is designed for speed rather than for overcoming great loads." (p. 205). "From time to time special foodstuffs are advertised as having special qualities of providing extra energy. . . . These are, at best, only calories in an expensive form." (p. 294). "Because of the larger energy requirement during work, the large man accumulates heat under conditions in which the smaller man attains a heat balance." (p. 313). "Negroes can stand humid heat better than white workers." (p. 314). "Women do not begin to sweat until the environmental temperature rises two degrees above the threshold for sweating in men, and the amount of sweating is less." (p. 321). "Muscular form is changed if the training is begun at an early age. The skeleton of the youth is also affected by training so that running may actually produce a 'runner' type." (p. 275).

The relevance of "Physiology of Exercise" to many of the problems of physical anthropology should be clear.

ANATOMICAL OBSERVATIONS IN A GORILLA GORILLA

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EIGHTEEN FIGURES

Bushman, the widely known lowland gorilla (*Gorilla gorilla*) in the Lincoln Park Zoo, Chicago, died on January 1, 1951. A description of the clinical and pathological findings can be found in another report (Steiner et al., '54) to which this paper is complementary. The extensive ante-and post-mortem changes make a complete anatomical description impossible, but certain features were of interest and, in view of the paucity of histological descriptions of the viscera of the gorilla, these are presented herewith. A few comments are also made on the gross anatomy, which, in some minor respects, differed from that described by others. Except for the abnormal features stressed in our other report, the organs are believed to be within normal limits. Straus ('53) has recently written that ". . . the anthropoid apes have not found their way under the microscope, except on relatively rare occasions," and Yerkes has stated ('51) that "Incredible though it may seem, of gorilla histology, embryology, and structural genetics very little is known."

Bushman died at age 22 years after a remittent illness lasting about 6 years of what is believed to be a deficiency, chiefly of vitamin B complex. The principal manifestations resembled those of a chronic neuritic and cardiac type of dry beriberi, pellagra, and pyridoxine deficiency combined, per-

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haps, with other obscure and unknown nutritional defects, despite extraordinary efforts to maintain an adequate diet. He was, in general, well-nourished and physically mature despite which the reproductive tract was not only underdeveloped but abnormal. The neurological disorder and the testicular sclerosis resemble the findings in several other captive gorillas. The poor survival in captivity, failure of reproduction, and presence of special degenerative lesions in the absence of inanition taken in conjunction with the unexplained peculiar limitation of habitat in nature to two separate areas in Equatorial Africa, suggest that the gorilla may have some unique qualitative or quantitative nutritional requirement not possessed by the other anthropoid apes.

It is believed that the pathological findings in Bushman explain what has heretofore been called sexual immaturity in some large captive gorillas. For present purposes the pathological findings must be mentioned in order that due allowance be made for them so that a more correct understanding of the gross and microscopic anatomy may be achieved. The present findings shed new light on those reported by others, and an effort will be made to integrate and reconcile these views. To do this most effectively, the discussion will follow immediately after each description.

For calculating weights of organs relative to body weight, the weight of about 500 lbs. at death was used. The maximal during life was 560 lbs., and the standard for some years was around 550 lbs. The body at necropsy was still obese and there was no evidence to suggest that the animal had been in negative nitrogen balance except possibly as concerns the liver and this situation has special explanations. It is believed, therefore, that use of the terminal body weight gives more nearly correct organ weight ratios than would use of the maximal weight.

The examination was begun three hours after death and lasted for 8 hours, during which time considerable body heat was retained, due to the large size, obesity, and the thick pelt. Postmortem changes, therefore, developed in some tis-

sues. The nervous system was first examined and it is best preserved.

ANATOMICAL OBSERVATIONS

External appearance

The body weighed about 500 lbs. The general configuration is shown in figure 1, and in our other paper. He was a well-developed, large, male gorilla apparently adult in all respects except for very small external genitalia. The head was large and the crest well-developed. The neck was short and thick. The trunk was large, with broad chest and protuberant abdomen although the latter was hardly noticeable in the dorsal recumbent position. The shoulder girdle appeared better developed than the pelvic and the upper extremities were longer and larger than the lower. Abnormal findings in the left lower extremity have been described elsewhere.

Skin

The dark greyish-black skin was covered by a thin growth of coarse blackish hair, up to 4 cm long. The skin was thick and stiff but pliable. It varied from 1 to 1.8 cm in thickness in regions measured. Microscopic sections taken from the dorsal thoracic midline showed a specimen which measured 1.7 cm thick (figs. 2 and 3). It appeared essentially human except for its relative proportions and dimensions. In the epidermis only three layers were visible of which only two were well-developed. The stratum corneum comprised from half to two-thirds of the epidermis. It contained many evenly-distributed clusters of brown pigment and its outer parts were loose and broken. The stratum granulosum formed a thin pigmented zone only one or two flattened cell layers thick. The Malpighian layer was from about 4 to 8 cells thick and it exhibited poorly-developed intercellular bridges. The basal layer consisted of a continuous row of low cylindrical cells heavily laden with blackish-brown pigment which was more abundant deep to than above the nuclei. Dermal melanoblasts were fairly numerous but chromatophores appeared rare. The

pigmented cells continued down in the dermal sheath of the hair roots to the level of the sebaceous glands. The epidermal appendages in the dermis were numerous and well-developed. The hair roots went down 4 to 5 mm from the outer surface. Comparatively small sebaceous glands were in proximity to the hair shafts about halfway down from the surface. Sweat glands were found near the ends of the hair roots or deeper. The papillary layer of the dermis was developed poorly or, in most places, not at all. The dermis was, on the whole, thick, dense, and relatively poor in nuclei. It consisted chiefly of large interweaving bundles of collagenic connective tissue. Centering at or below the level of the hair roots were numerous compartments of adipose tissue elongated to about 6 mm vertically to the surface and about 1.5 mm wide. They formed a distinct zone at this level and were separated from each other by narrow bands of connective tissue averaging about 1 mm wide. Deep to this zone, fat cells were few and scattered or in small groups separated by dense connective tissue. Distinct, well-developed bundles of smooth muscle connected the epidermis with the hair shafts deep to the sebaceous glands. Blood vessels were inconspicuous in the skin.

The interested reader is referred to a comparative description of the gorilla skin by Straus ('50).

Laryngeal air sacs

In removing the skin several serous pouches were encountered. They were entered in the neck medial to the sterno-cleido-mastoid muscles and in the front of the axilla, from where they extended widely. These pouches were empty and their opposing walls were in contact. They were lined by a pale, delicate, moist, smooth and glistening, semi-opaque lining. In several places the hand could be inserted into these sacs, but elsewhere they were reduced to flat slits by pressure of adjacent structures. They extended upward in the neck, possibly to the larynx. Their configuration was irregular and complete dissection to determine their extent, ramifica-

tions, and exact relationships was not possible. Microscopic examination of the wall of one pouch disclosed a single layer of greatly flattened cells lying directly on a dense connective tissue.

These pouches constituted the only major observed qualitative anatomical difference between gorilla and man.

Serous body cavities

The thoracic configuration and contents were different from those in man in size and in proportions. The obese mediastinum was wider than in man. The anterior pleural reflection from the mediastinal surface to the ribs was far out on the rib cages so that the antero-medial margins of the pleural spaces and the lungs were rounded. The pleural spaces were not immediately exposed when the sternum and adjacent costal cartilages were removed, as in man, because of this wide reflection of the pleura. The pleural spaces appeared relatively shorter from base to apex, and broader and thicker than the corresponding human structures. The lower chest aperture was very large. Microscopically, one section of visceral pleura taken at a point where there was no adhesion showed a group of fat cells. This is not ordinarily seen in man.

The pericardial cavity was completely covered anteriorly by fat. It was large, if not actually enlarged, and its shape was altered by the abnormal heart and increased amount of pericardial fluid described elsewhere, so that observations on size and shape are not reliable as standards. Its general relations, however, appeared essentially human.

The peritoneal cavity was wide at the upper or cephalad end; its lower end became narrowed to terminate in a relatively small pelvis. The anterior abdominal wall was thin, despite a considerable deposit of fat, and its muscles appeared poorly-developed in comparison with those elsewhere on the trunk. They may have been stretched by the excessive abdominal obesity. The position of the abdominal viscera and the

peritoneal reflections resembled those in man. The outstanding exception was the presence of numerous fibrous peritoneal adhesions in the anterior part of the abdomen, regarded as pathological, and of a fibrous fold or adhesion firmly binding the lower pole of the spleen to the lateral wall. The presenting abdominal structure was the obese greater omentum and, after this was removed, the large cecum and ascending colon were most conspicuous. Despite the relatively low diaphragmatic arches, the liver and spleen lay above the costal margins.

It is apparent from the careful studies of Schreiber ('32) that the abdominal cavity of primates shows a considerable degree of variation. In this general pattern, the gorilla has some unique although minor features which are more like man than like the monkeys. A large right colon was illustrated also by Koch ('37) in Bobby, the Berlin gorilla.

Respiratory tract

A detailed study of the upper respiratory tract was not made. The larynx was estimated to be about one-third larger than that in the adult human male. The vocal cords were distinct. The laryngeal mucous membrane was pale greyish-white despite considerable edema of the lateral ventricular walls below the vocal cords. No features different from the detailed descriptions of Kleinschmidt ('38) were seen. The trachea was relatively short, measuring only 13.1 cm from larynx to the carina. It was almost round, and definitely larger than in man. Microscopic sections showed a pseudo-stratified columnar epithelial lining and other microscopic features not recognizably different from the human equivalents. The bronchi bifurcated from the trachea and further divided as in man, and on microscopic sections no unusual antemortem anatomical features were seen.

The lungs *in situ* were larger than those of the average man but their heavy weights (1,110 gm, right, and 850 gm, left) were due to pathological changes and were not indicative of

their size. Their configuration was essentially human, but they were relatively shorter from base to apex and greater in girth, although rounded and less angular, than in man (as in plate 98 of Washburn, '50). The left lung had two, and the right had 4 lobes, the usual right lower being almost completely subdivided into two lobes by a deep fissure. The microscopic sections from the anterior portions, where they are not greatly altered by the pathological changes, show bronchi and alveoli which are not recognizably different from those in man (fig. 4).

Cardio-vascular system

The heart showed many pathological changes but the remainder of the vascular system was relatively normal except for a few sclerotic lesions in the aorta and the small vessels of the nervous system and heart. Because of the paucity of reports in the literature on the heart, it is not definitely known whether the 805 gm heart of Bushman was hypertrophic or not, but from the microscopic appearances, the relatively small size of the coronary arteries, and its wide and globular configuration it is believed that it was hypertrophic. Its large chambers were believed to represent dilatation. The distribution of coronary arteries, considered to be anomalous, has previously been described with the other pathological changes.

On microscopic examination only one difference which might be considered normal was found between this and the human heart. This consisted of adipose cell infiltration deep into the left ventricular myocardium. This condition is seen in the right ventricle of man so commonly as to be regarded as more or less normal if it is not excessive, but its presence in the human left ventricular myocardium is regarded as abnormal.

Washburn ('50), after studying two adult gorilla hearts, stated that they were more pointed than the human heart. This was not true in Bushman, and it is additional evidence for abnormality.

The aorta, which at the aortic orifice was 9.2 cm in circumference, tapered down rapidly below the arch to measure 5.2 cm at the level of the diaphragm and 4.9 cm at the bifurcation. Its histological structure resembled that in man (fig. 5). Three arteries arose from the arch; innominate, left common carotid, and left subclavian. The subclavian arteries to the large upper extremities were about twice as large as the common carotids; the iliacs were relatively small. The main arteries to the large abdominal viscera, however, appeared large. The diameter of the celiac artery was 0.9 cm as was that of the superior mesenteric. The main pulmonic arteries and veins, the portal system, the superior and inferior vena cavae, and the other large blood vessels appeared essentially human except for minor differences in size and relations. No histological differences regarded as normal were seen between the structure of these and human blood vessels.

Alimentary tract

No detailed anatomical study was made of the mouth. The distribution and amount of pharyngeal lymphoid tissue appeared essentially human. The large submaxillary salivary glands weighed 24.5 and 24.2 gm respectively. They were elongated ovals and soft. Their lobulation was coarser than in man. They were dark reddish-brown, a color which was not caused by hemochromatosis or other recognizable abnormality. They were composed predominantly of serous cells but with a fair proportion of mucous cells (estimated at 15%), arranged in a pattern in relation to the collecting tubules which was not dissimilar to the human picture.

The esophagus was large, thick-walled, and 40.6 cm long. Its wall in the contracted state was about 50% thicker and its diameter about 25% greater than in man. It was nearly straight, and semi-rigid. A cross section through the center of the distal third revealed that the inner circular muscle layer showed an occasional striated muscle fiber, but that nearly half of the fibers in the outer longitudinal layer were

still striated at this level. A section from the gastric cardia upward into the lower end of the esophagus exhibited pure smooth muscle, a stratified squamous lining epithelium with underlying mucous glands, and a transition zone to gastric mucosa resembling that seen in man; gastric glands with chief and parietal cells appeared almost at once.

The stomach lay chiefly to the left of the midline. In a state only moderately distended by fluid, it was large and thick-walled — about twice human size in both respects. Rugae were not conspicuous but the gastric pits were distinct. Microscopic sections of the cardia, fundus, and pylorus showed muscle and glandular structures resembling those seen in man. In addition, a large amount of adipose tissue was present in the submucosa of all parts except the pylorus. The duodenum was large but otherwise not remarkable. The jejunum and ileum together were 1,021 cm long and about 50% thicker and larger than the human small intestine. This compares with 945 cm in the gorilla male of Elftman and Atkinson ('50). The large intestine was 168 cm long. The cecum, ascending colon and hepatic flexure were very large, measuring, at the maximum in the lower ascending colon, 30 cm in circumference, whereas the human colon at this point is rarely over 14 cm even in the distended state. The remainder of the colon was proportionally much smaller although larger than in man. There was no pedunculated, redundant sigmoid loop, but the descending colon passed to the rectum via a small curve. The appearance of the colon, with the large proximal portion, resembled that illustrated by Koch ('37) in his figure 2 for Bobby, the Berlin gorilla. The longitudinal taenia were very large and conspicuous (fig. 6), as were the haustral markings. In cross section the taenia were oval and measured about 11×5 mm and on microscopical sections they were simple enlargements over the condition seen in man. Lymphoid tissue was inconspicuous in the ileum and proximal part of the colon but solitary lymphoid follicles were conspicuously large and numerous in the descending and sigmoid regions. A thick layer of adipose tissue was seen in the submucosa

on microscopic sections. Elftman and Atkinson ('50) did not comment on any disproportion between right and left colon in their two gorillas and in that of Raven. It is possible that a difference exists in size of the proximal end of the colon between wild and captive gorillas.

The appendix was 12.7 cm long but slender. It lay free and was of almost uniform caliber, measuring 0.9 cm. Its proximal end was funnel-shaped (fig. 7). It showed a series of distinct, pedunculated, obese appendices epiploicae. On microscopical section the appendix was poor in lymphoid tissue and it exhibited a large amount of neurofibromatous tissue, forming a wide zone in the mucosa and extending into the submucosa. The appendix in size resembled that reported by Elftman and Atkinson ('50), and Koch ('37), but it was only half that reported by McKenney et al. ('44) for a captive male, whose appendix measured 25.5×2.0 cm. This gorilla died of acute coccidioidomycosis and it is possible that the appendix was enlarged due to lymphoid hyperplasia. Flower (1872) had previously reported the longest appendix—21.5 cm.

Liver and biliary tract

The liver weighed 2,200 gm. For reasons given elsewhere, it is believed that this represents an atrophy and not a normal weight. The liver had three large lobes and one smaller one, of which two were right and two left; caudate and quadrate lobes were not developed. Except for its greater lobulation, the liver appeared human both grossly and microscopically. The lobules were not demarcated by distinct fibrous tissue.

Raven ('50) illustrated in his combined plates 91 and 92 and figure 39 a total of 6 lobes, all except the quadrate distinctly developed, in a wild, young adult lowlands gorilla. Six lobes are also described in two gorillas by Elftman and Atkinson ('50). Koch ('37) found 4 lobes of which three were right and one left. It is apparent that the lobulation of the liver is more variable than in man.

The gall bladder was found at the expected site on the right central liver lobe. It was large, measuring 17.5 cm in

length and 4.5 cm in greatest diameter. It was slightly tortuous and roughly carrot-shaped with the large proximal end attached to a fossa in the liver, and the tapering but round-tipped distal end entirely buried within liver substance and so presenting itself at the anterior surface of the liver (figs. 8, 9). The valves at the gall bladder neck were few and simple; bile could easily be evacuated from the bladder by slight pressure, and this neck region was easily opened by simple dissection with the scissors, a maneuver ordinarily difficult in man. The extrahepatic bile ducts appeared human in size but their relative lengths were different. The common duct was 9.2 cm, the cystic was 2.5 cm, and the hepatic was 2.5 cm long. The latter bifurcated outside the liver into a long (5.2 cm) left hepatic and a short (2.0 cm) right hepatic duct, both measured outside the liver.

This gall bladder exhibited definite but minor differences from that illustrated by Raven (his figs. 39, and 40) where the bladder was almost pedunculated, as in man. He also illustrated the simple condition of the valves at the bladder neck. One gall bladder described by Elftman and Atkinson ('50) lay in a shallow fossa but the other had no fossa. All reached to the liver margin as in the present instance. It is apparent that the gall bladder of the gorilla also exhibits a number of minor variations. Although it extended only to the anterior liver margin, the 17.5 cm length of the present gall bladder is greater than that described by others, i.e., 14 cm for Bobby (Koch).

Urinary system

The kidneys were dark reddish-brown, plump, and firm. The right kidney weighed 268, the left 280 gm. The left kidney measured $13 \times 7 \times 4.5$ cm. The capsules were thin and the surfaces were absolutely smooth and without any persistent fetal markings. The cortex averaged 16 and the medulla 28 mm in thickness. The renal pelves were small and simple (fig. 10). There were no elaborate calyx systems but only

funnel-shaped expansions of the upper ends of the ureters which attached within shallow concavities on the medial surfaces of the kidneys to relatively flat medullae over areas about 2 cm in greatest diameter. They conformed essentially to the type A kidney of Straus ('34), with many secondary pyramids. Microscopically, except for their greater thickness, the kidneys were not recognizably different from those of man (fig. 11).

Raven ('50) illustrated in his plate 92 extensive persistent fetal lobulations in a wild adult male gorilla from the French Cameroon. The kidneys illustrated by Elftman and Atkinson ('50) in their plate 102, however, are smooth. It is probable that in the gorilla, as in man, considerable difference exists in this regard.

The ureters were 36.5 cm long and 1.8 cm in circumference. The bladder appeared relatively small and thin-walled. Trabeculation was not seen. The internal urethral meatus was round and it remained open, with a diameter of 8 mm.

Generative organs

The penis was small, black, soft, and flabby. It measured about 6×1.2 cm. It had no foreskin and an inconspicuous bulbous glans. The small, non-pendulous, scrotum contained testes which weighed, with their epididymes, 23 and 19 gm. They resembled human testes in size and shape. Microscopically these testes were highly abnormal, showing a severe atrophy and sclerosis of the seminiferous tubules, and other changes described elsewhere. The interstitial cells of Leydig, however, were increased not only relatively but probably also actually. Their functional state is not known so it is uncertain whether the other generative organs were hypoplastic if not atrophic secondarily to the gonadal disease, and whether the anatomical descriptions of the generative organs given here are those of a normal male gorilla.

The prostate was small, soft, pale tan, and symmetrical. Its maximum dimensions were $3.2 \times 2.6 \times 1.0$ cm. The sem-

inal vesicles appeared human in size and in their convolutions. They contained thin, clear, mucoid fluid. There was one small nipple on each pectoral region arising from flat skin without any mound. Microscopically, as already stated, the testes were highly abnormal. The prostate showed convoluted glands with low columnar epithelium in a fibromuscular stroma. The seminal vesicles appeared essentially human, except for the absence of spermatozoa.

Small external genitalia appear to be a constant finding in the gorilla, both wild and captive (Wislocki, '36; Schultz, '38). Hooton ('46) comments that the genital organs of apes, unlike those of man, undergo a process of atrophy as the animals grow but he gives no reference to this observation. From the recorded data, one is inclined to regard it in the penis as hypoplasia rather than atrophy. In the testes there is unquestionably an element of atrophy but at the same time the possibility that it is added to an element of hypoplasia cannot be eliminated. The only histological studies of the testes of captive gorillas, which are available to us, those of Bobby, the Berlin gorilla (Koch, '37) and Bushman, both reveal severe atrophy and sclerosis of the seminiferous tubules. Such a process is likely to have caused reduction in the size of the testes. The small testes of M'Bongo, a 618-lb. specimen aged 15 years at San Diego, revealed no spermatozoa on smears made from the testes and he was considered as sexually immature (McKenney et al., '44). We have elsewhere discussed the probability that the sclerotic changes are on a nutritional basis. It is highly desirable that studies be made of the size and histological composition of the testes of wild gorillas to account for their small size, and of young captive specimens at all ages to study the pathogenesis and ultimate prevention of the sclerosis which results in sterility.

Spleen, hemopoietic, and lymphatic system

The spleen weighed 372 gm and measured $18.8 \times 9.7 \times 3.8$ cm. It was, therefore, a relatively plump organ. It greatly

resembled a human spleen, except for its larger size. It had no fetal clefts or other unusual external markings. Its microscopic appearance resembled that in man and it is presumed to have been relatively normal except for the presence of an excessive amount of brown (hemosiderin) pigment and a reduction in the lymphoid elements.

This spleen was unlike that reported by Raven (his plate 88) who illustrated a long, slender, narrow, small curved organ. Since his specimen was obtained from a wild gorilla killed in French Cameroon, it presumably was exsanguinated and contracted, although there was no microscopic confirmation of this point. The same comment may be made about the spleen described by Elftman and Atkinson ('50) which measured 33×7 cm. The spleen of zoo-dwelling Bobby (Koch) was intermediate in shape between these extremes; it measured $18 \times 7 \times 3$ cm so that although it was described as tongue-like, it was relatively broad. It was also described as showing marginal clefts. The shorter spleens of the two captive gorillas compared with the longer wild ones may be explained in part, if not entirely, by the fact that they were removed and examined in the fresh state, in which condition they may contract, like those of other animals after removal soon after death. The spleen of San Diego's M'Bongo weighed 680 gm, but this great enlargement was, no doubt, caused by the fatal disease, coccidioidomycosis, which, in its disseminated form is known to involve this organ.

The bone marrow was examined in only a few locations. Insofar as the studies went, no differences from man were seen in the distribution of red and yellow marrow and, microscopically, hemopoiesis appeared to be proceeding as in man.

The lymph nodes were smaller in proportion to body and organ size than in man in all locations except the cervical region. The nodes were darker in color (reddish-brown) than in man, but on microscopic examination no significant difference was seen from moderately atrophic human nodes and no cause was apparent for the darker color. A similar dif-

ference in color was not mentioned by Raven in a wild gorilla (p. 25) but that was a preserved specimen.

Endocrine system

The pituitary has been described by Rasmussen and Rasmussen ('52).

The thyroid gland weighed 13.5 gm. Its flat isthmus measured $4.6 \times 0.8 \times 0.6$ cm. At each end of the isthmus was a small, flat lateral lobe of which the right measured $3.7 \times 2.7 \times 1.2$ cm, and the left $4.0 \times 2.8 \times 1.2$ cm (fig. 12). The lateral lobes were direct end-on prolongations of the isthmus. The isthmus was applied to the front of the trachea, and the lateral lobes diverged outward and upward and finally converged backward to enclose more than two-thirds of the tracheal circumference. The tips of the lateral lobes were between the larynx and pharynx. The thyroid was flabby, soft, and reddish-brown. Its capsule was delicate and it was slightly irregular or lobulated. Adipose tissue accompanied blood vessels into the gland. Microscopic sections revealed small, fairly uniform acini with low cuboidal epithelium, lying in a very abundant fibro-vascular stroma which was edematous and infiltrated by adipose tissue. The acini were separated by the stroma singly or into small groups (fig. 13). A small nodule, considered to be a Hürthle cell adenoma, was found.

The thyroid of a wild male 450-lb. mountain gorilla described by Venable and Grafflin ('39) weighed about 11 gm. They observed the absence of a lower pole, the far posterior position of the upper pole, and the higher position compared with the human gland. Microscopically, their gland compared with the present case (Grafflin, '40) showed more variation in the size of the follicles, and it lacked the edematous fibrous stroma containing adipose tissue cells. It is probable that both the amount of stroma and its edematous and adipose character in Bushman were abnormal.

The thymus was buried in anterior mediastinal and lower cervical fat from which it was dissected with ease. It weighed 14.8 gm and was pale yellowish-grey. It extended from the anterior surface of the lower third of the pericardial cavity to, at one point, the thyroid (fig. 14). It was divided into two main lobes, connected only by areolar tissue, of which the right lobe measured $12.6 \times 2.6 \times 0.6$ cm and the left $11.2 \times 2.0 \times 0.6$ cm in maximum dimensions. The caudad ends were spread out on a wide area on the anterior-lateral surfaces of the pericardial sac. From here they converged, to lie side by side in their middle thirds, but the upper parts diverged and became pointed. Microscopically the thyroid showed much involution and replacement by fat. It was estimated that three-fourths of the gland was adipose tissue. Both lymphoid and reticular areas persisted although they were not distinctly divided into cortex and medulla (fig. 15). Hassall's bodies were small and inconspicuous, and they showed various stages of degeneration and atrophy. Microscopically the thymus was indistinguishable from the involuting gland commonly seen in human adults who have been ill for some time.

It is apparent from the microscopic sections and from the gross description by Raven (his p. 25 and fig. 4) on a wild French Cameroon adult male, whose thymus was 21 cm long and showed little adipose infiltration, that the thymus of Bushman had undergone involution if not actually also atrophy (as did other lymphoid tissues). The shorter length in the present case may in part represent shrinkage as the measurements were made on the formalin-fixed specimen. Certainly it persisted better than in the female described by Washburn ('50) where the thymus had completely involuted. It seems clear, however, that the thymus in the gorilla occupies the same site as in man.

The left adrenal gland weighed 9.3 gm and measured $6.1 \times 3.9 \times 1.9$ cm; the right was 8.5 gm and measured $8.5 \times 3.2 \times 1.6$ cm. The left gland was triangular and flat and human in appearance, but the right was greatly elongated

along the inferior vena cava. Both glands were irregular and convoluted (fig. 16). The glands had thin fibrous capsules, a narrow yellow outer cortical layer, a wider brown inner cortical zone, and a narrow pale grey medulla. Microscopically they showed an atrophic narrow glomerular zone, slight irregularity of the cords of the fascicular zone, and a narrow inconspicuous reticular zone (fig. 17). Lipid was irregularly scanty in all zones but more in the inner than the outer. The medulla appeared normal. The large veins had irregular bundles of smooth muscle in their walls. The adrenals were interpreted as not entirely normal, and they resembled the glands from persons who succumbed to prolonged illnesses. The longitudinal muscle bundles in the central veins appeared to be less well-developed than in man.

The pancreas weighed 105.5 gm and it measured 31.5×6.5 (head) $\times 1.8$ cm. It was very long, in keeping with the great breadth of the upper abdomen. It was almost twice the length of the human pancreas but relatively more slender and its head was relatively much smaller. It was dark reddish-brown. The lobules were much larger than in man. Despite severe autolytic changes, it was apparent that the acinar and duct system microscopically resembled that in man. The number of islets appeared essentially human but their size averaged larger. Moreover, a few showed distinct fibrous capsules (fig. 18).

Elftman and Atkinson ('50) described a pancreas 20 cm long in which the volume of the head also was small in proportion to the body. Their plates 101 and 102, however, illustrate a pancreatic body whose size, relative to that of the adjacent structures appears much greater than that found in Bushman.

Except for its greater length, the pancreas in the present case resembled that described by Koch ('37). He commented on the dark color of the pancreas in Bobby and considered it due to suffusion by blood pigment. In the present case, this explanation is improbable; there is no explanation in path-

ology for this dark color and consideration must be given to the possibility that it is normal for gorillas.

The striking and peculiar fibrous encapsulation of some of the pancreatic islets in the present case was not observed by Koch ('37) who described them merely as large. The significance, whether normal or abnormal, is not known.

The testes were described with the generative organs. The parathyroids were not examined.

Muscular system

A complete dissection of muscles was not made. They were firm, dark reddish-brown and well-developed except in the areas showing atrophy, described in our other paper. Yellow fat was abundant between muscles but grossly none was seen within muscle sheaths. The muscular development appeared greatest in the shoulders and arms but conspicuous also in the pectoral regions, neck, and scalp. The lower spinal, abdominal, and leg muscles, while not small, were not as conspicuous as others. Microscopically the muscles were not remarkable, except for more adipose cells between muscle fibers than are ordinarily seen in man (see other paper for illustrations). Some of the muscles were atrophic.

Skeleton

No systematic dissection was made of the skeleton. Several joints were opened and they seemed to be within normal limits.

Nervous system

The nervous system showed a number of pathological lesions which are described and illustrated in our other paper.

COMMENTS

The present author has recently had the opportunity of making a postmortem examination (for Professor Heinrich Klüver) on an adult female night monkey (*Aotes trivirgatus*),

a New World monkey. Disregarding size, it is possible to say that in the anatomical configuration and the relations of many viscera the differences between *Aotus* and *Gorilla* were much greater than between the gorilla and man. Examples in support of this statement include the mesenteries and relationships of the colon, the spleen, pancreas, liver, adrenals, and others. The appearance of these structures in the gorilla has been given. In *Aotes*, the very greatly elongated spleen has numerous vessels entering in a row along the lesser curvature; the pancreas is a flat membrane-like organ although lobulated; the colon lacks true transverse and splenic segments but descends through a pendulous mesentery to the pelvis, passing medial to the left kidney; the liver is extensively lobulated; the adrenals are smooth, slightly flattened oval organs. The detailed findings in this monkey will be published elsewhere.

Through the courtesy of Professor Smith Freeman, it has recently been possible to study some of the organs of "Lady Congo" an adult female gorilla. A separate publication is projected on the findings but for present purposes it can be said that the pancreas was not pigmented reddish-brown as in Bushman and Bobby (Koch) but had the pale yellowish-tan color characteristic of the human pancreas. It may be assumed, until further evidence is available, that the dark pigmentation is abnormal.

SUMMARY

Some gross and microscopical anatomical observations are recorded and illustrated on a 22-year-old lowland captive ("Bushman") gorilla (*Gorilla gorilla*). A complementary paper is published elsewhere on the numerous pathological lesions. The findings are briefly compared with man and with those reported in the literature on other gorillas. Differences are recorded in the relative size and shape of many organs.

The most conspicuous anatomical structure absent in man but found in the gorilla was the laryngeal air sacs. A dark pigmentation of the salivary glands, lymph nodes, and pan-

creas was noted but its chemical causes were not recognized and it may be abnormal.

Histologically, the organs and tissues can be divided into 4 groups:

- (a) Those indistinguishable from man (lung, aorta, liver, gall bladder, urinary bladder, spleen, lymph nodes, bone marrow, thymus).
- (b) Those qualitatively distinguishable from man (laryngeal air sacs).
- (c) Those distinguishable from man because of differences in proportions or size, either smaller or larger (skin, trachea, stomach, small intestine, kidney, prostate).
- (d) Those distinguishable from man because of quantitative differences in known locations (esophagus, pleura, myocardium, medium-sized arteries, stomach, colon, thyroid, adrenals, pancreas, skeletal muscle).

It is possible that future studies will justify reclassifying some of these findings either as pathological or as belonging in some other category.

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PLATES



1 Photograph during life — squatting posture

PLATE 2

EXPLANATION OF FIGURES

- 2 Skin. Photomicrograph ($\times 13$). Formalin fixation, celloidin embedding, hematoxylin and eosin stain. Shows nearly the full thickness of skin in the dorsal midline with number and topographical relationships of the structures described in the text.
- 3 Skin. Photomicrograph ($\times 23$). Zenker's fixation, paraffin embedding, hematoxylin and eosin stain. Higher power to show the epidermis and the dermal appendages.
- 4 Lung. Photomicrograph ($\times 53$). Zenker's fixation, paraffin embedding, hematoxylin and eosin stain. Shows lung resembling that of man.

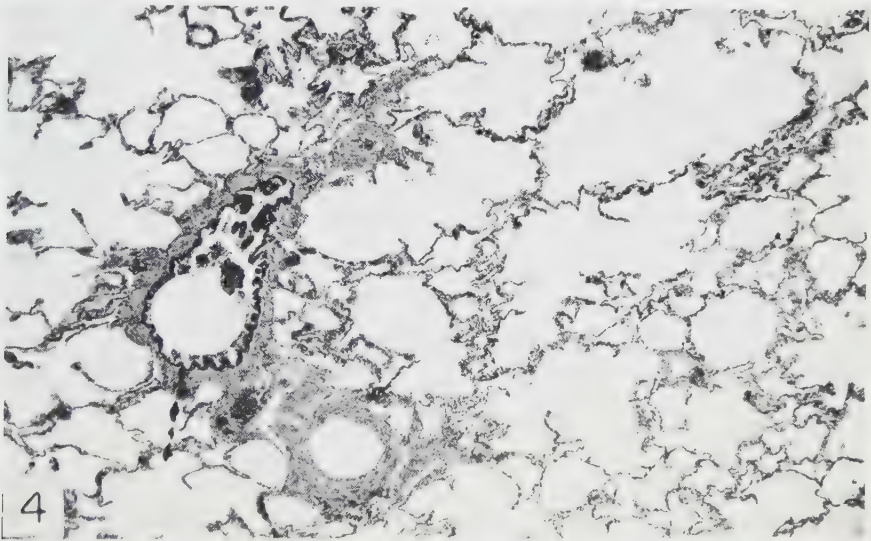
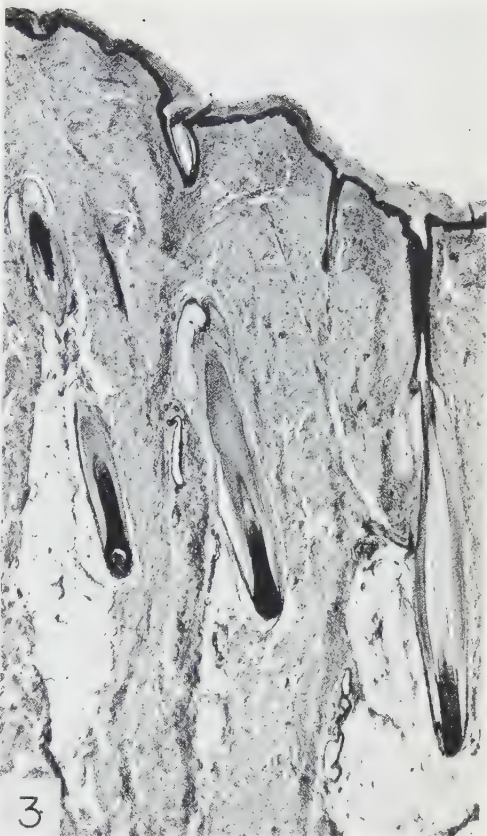
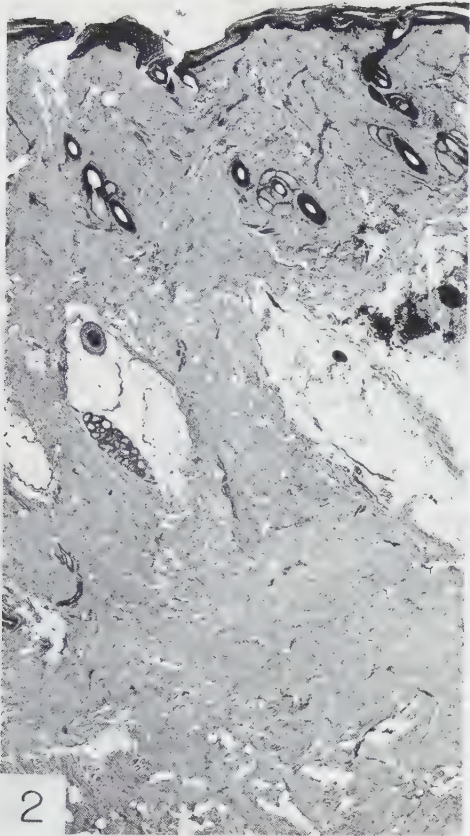


PLATE 3

EXPLANATION OF FIGURES

- 5 Thoracic aorta. Photomicrograph ($\times 85$). Zenker's fixation, paraffin embedding, hematoxylin and eosin stain. Shows a structure indistinguishable from that in man.
- 6 Photograph showing one of the large taenia of the colon.
- 7 Photograph showing the curved appendix with funnel-shaped proximal end.
- 8 Photograph of the tip of the gall bladder presenting itself beneath the liver capsule.
- 9 Photograph of the distal third of the gall bladder. At this level it was about two-thirds buried in liver substance.

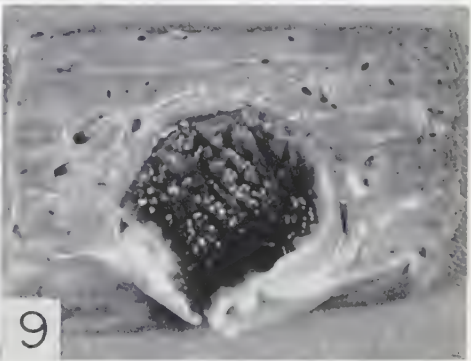
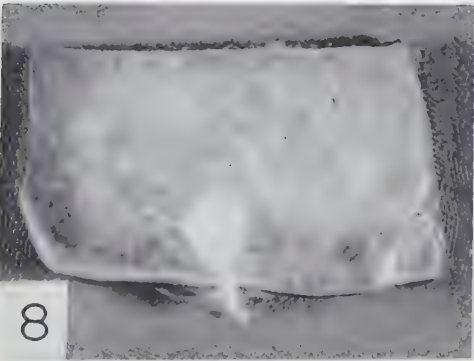
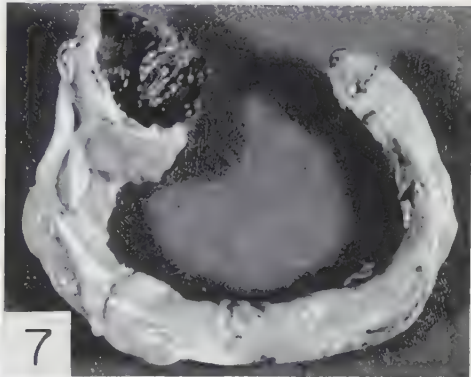
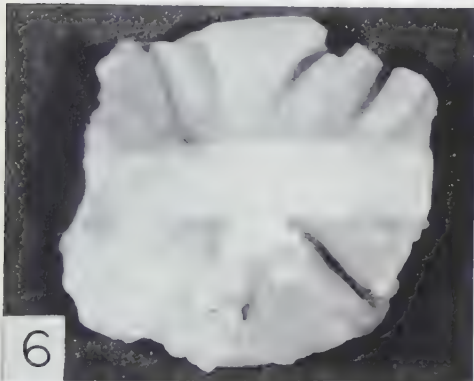
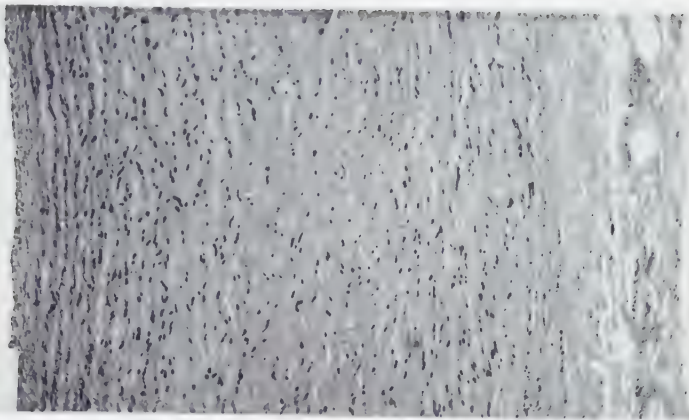


PLATE 4

EXPLANATION OF FIGURES

- 10 Photograph of kidney showing simple renal pelvis. The distinction between cortex and medulla is here exaggerated.
- 11 Kidney. Photomicrograph ($\times 23$). Zenker's fixation, celloidin embedding, hematoxylin and eosin stain. Low power view showing the topography of the cortex.

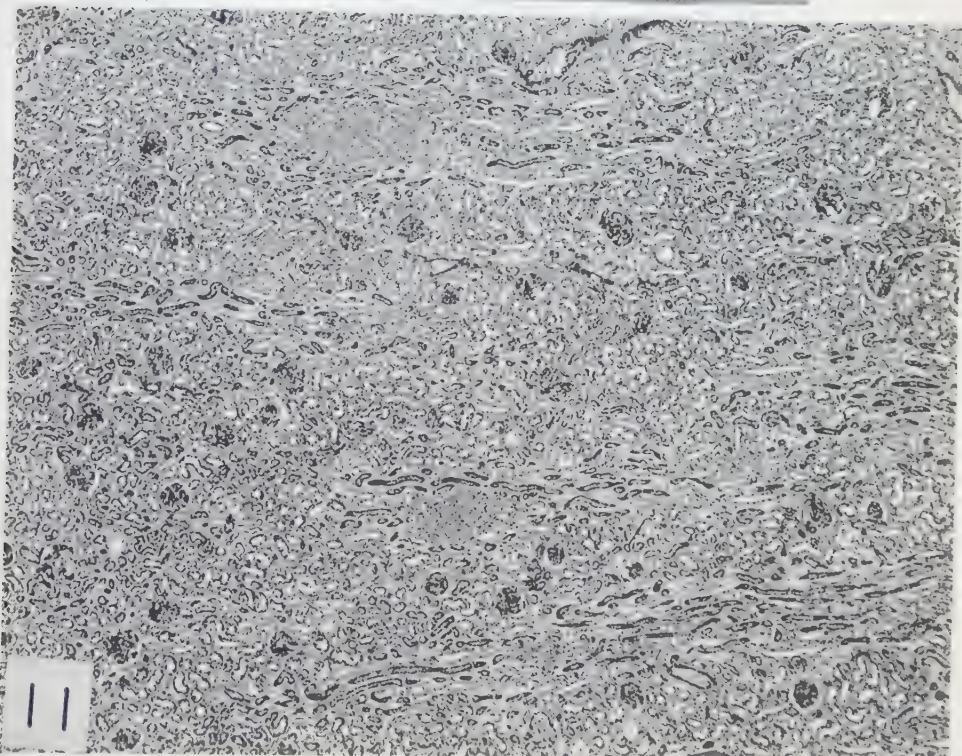
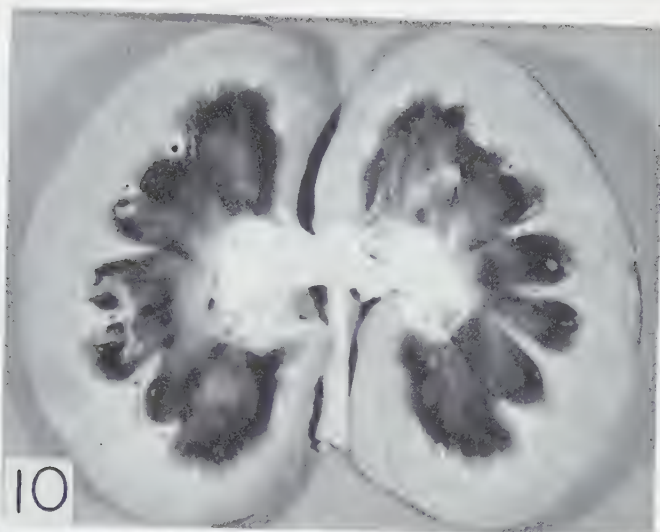


PLATE 5

EXPLANATION OF FIGURES

- 12 Photograph of thyroid gland which was an elongated, flattish organ.
- 13 Thyroid gland. Photomicrograph ($\times 26$). Formalin fixation, celloidin embedding, hematoxylin and eosin stain. The small acini separated by an abundant, pale, obese stroma is evident.

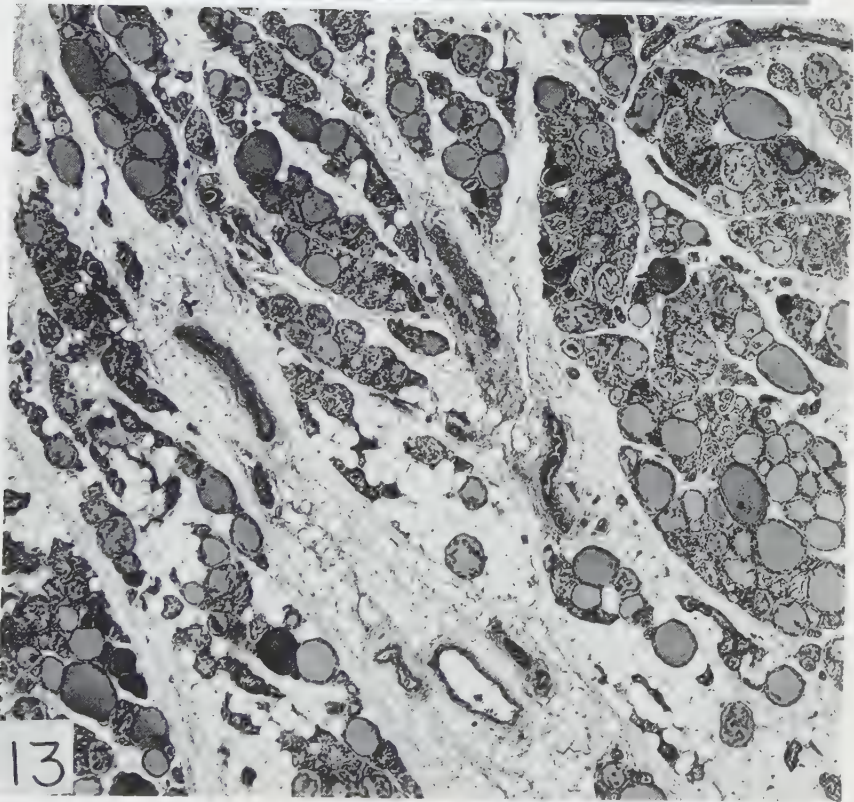
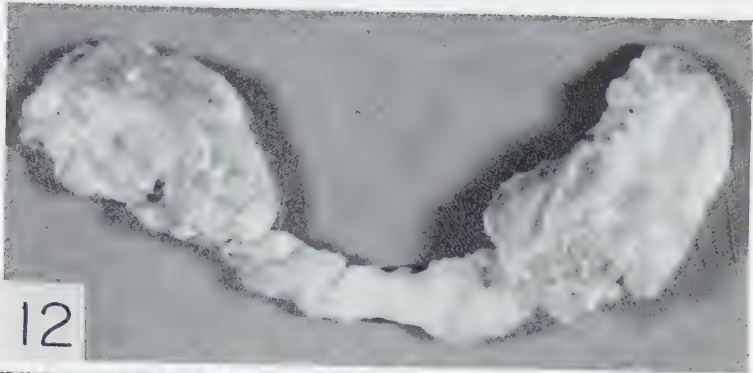


PLATE 6

EXPLANATION OF FIGURES

- 14 Thymus gland. Photograph showing bilobed character and configuration.
- 15 Thymus gland. Photomicrograph ($\times 90$). Formalin fixation, celloidin embedding, hematoxylin and eosin stain. Shows involution and poor differentiation into cortex and medulla.

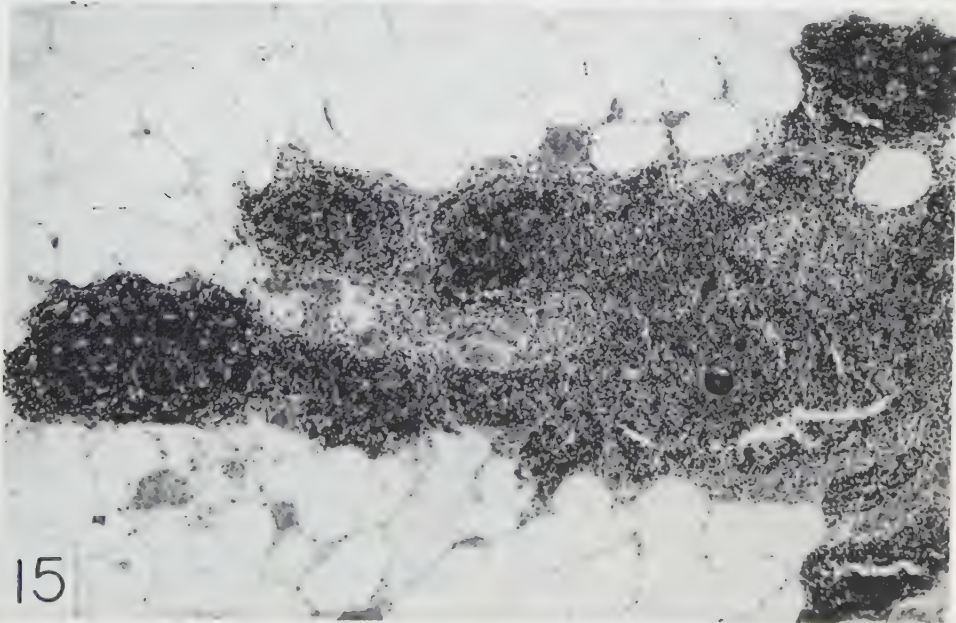
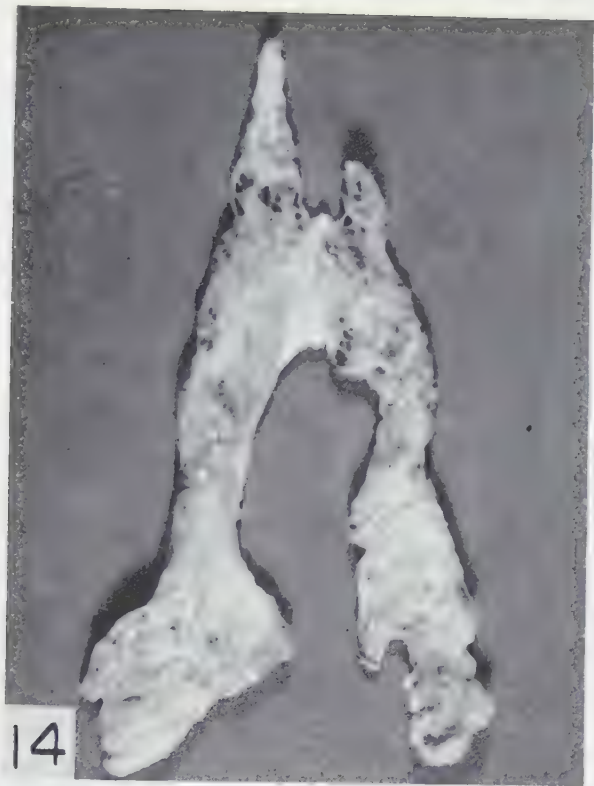
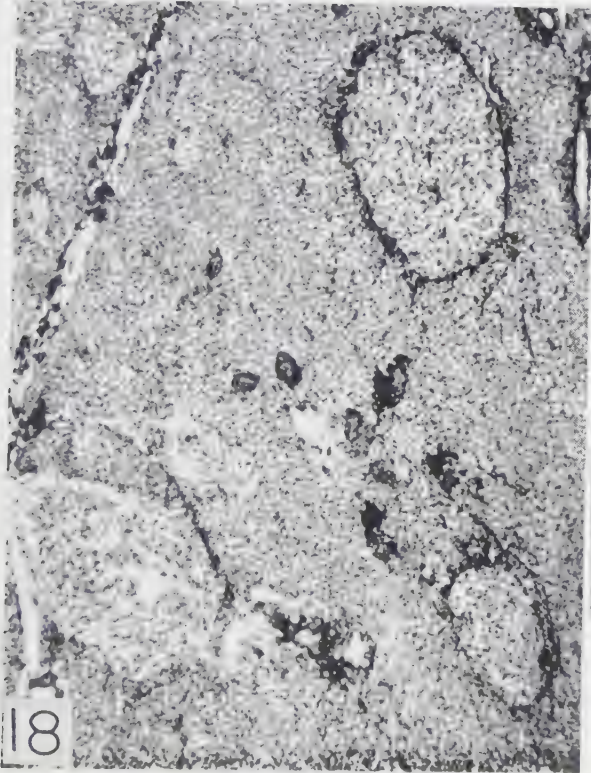
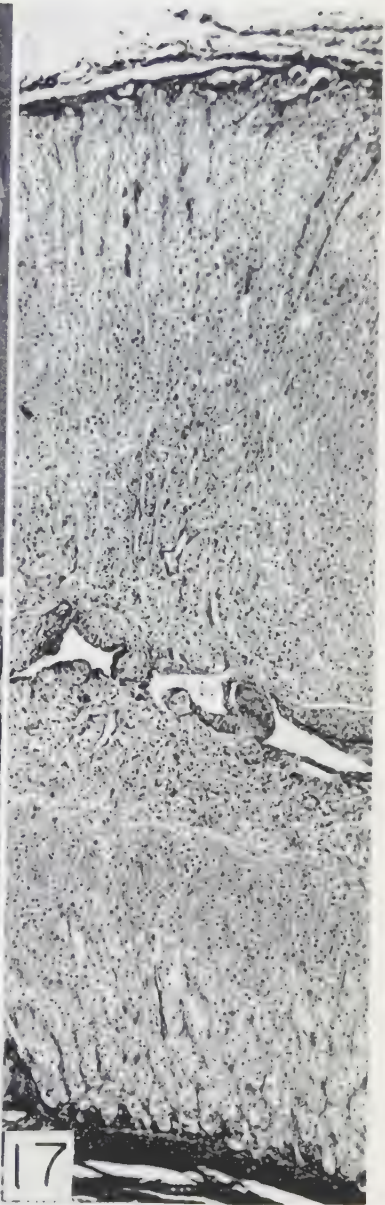


PLATE 7

EXPLANATION OF FIGURES

- 16 Adrenal glands. Photograph showing external configuration.
- 17 Adrenal gland. Photomicrograph ($\times 57$). Formalin fixation, paraffin embedding, and Mallory-azocarmine G stain. Section through the gland showing arrangement of the zones.
- 18 Pancreas. Photomicrograph ($\times 70$). Zenker's fixation, paraffin embedding, Mallory-azocarmine G stain. Shows three large islets, two of which have distinct fibrous capsules.





APES AND APE LORE IN THE MIDDLE AGES AND THE RENAISSANCE. H. W. Janson. (384 pp., illustrations and figures. 3.3.0 The Warburg Institute, University of London, 1952.) — For the student of primatology, this inquiry into the significance of the “ape” in Late Mediaeval art gives cultural background evidence that shows man’s fascination with his near relatives is not a recent thing. Janson’s last chapter, *The Coming of the Anthropoids*, adds evidence to what we already know about the impact of the discovery of the great apes on man’s ideas of human nature. In this book we get more of a picture of the human than the non-human animal.

PREMATURITY, CONGENITAL MALFORMATION AND BIRTH INJURY. By L. Emmett Holt, Jr., Theodore H. Ingalls and Louis B. Hellmon (eds.). Association for the Aid of Crippled Children, New York. xiii + 255 pp. 1953. \$4.00.— This volume, the collected proceedings of a two-day conference in 1952, brings together 34 separate contributions in the broad field of prenatal development. It is outstanding in the wealth of material included, and in the way that the discussion material is interwoven into the text.

For the experimentally minded there is a 15-page section on the principles underlying experimental malformation, including a discussion of the effects of simulated high altitude. Here “Andean Man” is introduced, with some consideration of the effect of altitude on fertility, human and otherwise. (Allegedly Andean cats go down to lower altitudes during pregnancy!) There is also a contribution by F. Clarke Fraser of McGill on congenital malformations produced by cortisone, which as we know functions as a growth inhibitor.

Fetal anoxia, isoimmunization, enzyme development, and adaptation in enzyme systems are among the topics considered. One observation, by Worcester, may be especially interesting to human biologists. An “epidemic” of pilonidal sinuses in 1940–41 was finally attributed not to viral action, but to a pediatric interne with a fondness for this diagnosis.

This book shows how the value of a conference can be increased by making it available to a wider audience.— S. M. GARN.

THE GENERA AND SPECIES OF THE AUSTRALOPITHECINAE

J. T. ROBINSON ¹

Transvaal Museum, Pretoria

SEVEN FIGURES

The taxonomy of the Australopithecinae has been in need of revision for a long time and in the light of the recent advances in our knowledge of this group this task may now be undertaken with some profit.

The nomenclature most generally used at present is that outlined by Broom ('50), though there is widespread dissatisfaction with this scheme, which is as follows:

Subfamily: (1) Australopithecinae

Australopithecus africanus

Plesianthropus transvaalensis

(2) Paranthropinae

Paranthropus robustus

Paranthropus crassidens

(3) Archanthropinae

(Australopithecus) prometheus

A slightly later classification (Mayr, '50) goes to the opposite extreme. In this, all the australopithecines are lumped with fossil and modern man in a single genus with three species, one of which (*Homo transvaalensis*) includes all the australopithecines. Broom's classification is that of a determined splitter and Mayr's that of an equally determined lumpier. Washburn and Patterson ('51) have suggested that the facts can be most accurately expressed by placing all the

¹I wish to record my grateful thanks to the Nuffield Foundation, London, for a grant, the receipt of which resulted in the discovery of some of the specimens on which the conclusions are based.

australopithecines in a single genus of their own, *Australopithecus*.

Mayr ('50) touches on a point of some importance to hominid classification when he asks, "What is the cause of this puzzling trait of the hominid stock to stop speciating in spite of its eminent evolutionary success?" He answers this question by pointing out that the reason is "man's great ecological diversity" and the fact that man is "slow in establishing isolating mechanisms." He regards modern man as being less variable than the earlier members of his lineage and that never more than one species of hominid has existed at any one time. But can the matter not be taken further than this? The reason for man's great ecological diversity is surely closely bound up with his superior intelligence. Substituting "euhominid" for "man," it is clear that the one outstanding euhominid characteristic marking off this group from all other animals is relatively great intelligence. Euhominids manufacture tools to perform the functions of structures which in other animals could only be developed by selection over a long period of time. Not only this but man can also make a wide variety of other objects performing functions impossible in any other animal. He can artificially adapt himself to climate by developing clothing, housing, temperature controlling devices, etc., which allow him to colonize the arctic and the tropics as well as more temperate climes. By agricultural practices he can maintain large populations in a limited area while an animal population is dependent on the natural produce of the area in which it lives. Behind all this lies man's intelligence. In the very early stages of euhominid-hood this capacity for artificial adaptation was slight compared to that of the present time but once the deliberate manufacture of artifacts had begun this adaptive capacity had already well outstripped that of other animals.

This marked ability for artificial adaptation is in itself a powerful deterrent to speciation, but is not the only one. Another, briefly mentioned by Mayr, is man's strong tend-

ency to intermix. Intermixture is not common in nature; many instances are known of forms, occupying the same or overlapping territory, which can interbreed but in fact do not in the wild state. This does not seem to be true of sexually promiscuous man: if it is possible to intermix with another form, some intermixture will occur. There is always a certain amount of gene flow between the various groups of man. Man has always been a migrant but today more so than in the past — a fact which facilitates intermixture.

As a result of the above facts the effect of natural selection on man is reduced and modified and isolating mechanisms are slow to develop. Consequently euhominids have a slightly different evolutionary pattern from that of other animals. As a result the various races of man today are all conspecific whereas, but for the operation of these two factors, they would almost certainly have been specifically distinct.

It seems to me, therefore, that one cannot agree with Mayr that in the early stages of euhominid development intra-specific variability was even greater than at the present time. The australopithecines had not yet reached the artifact-manufacturing stage and were, on the whole, rather small brained. The above two factors — the first at any rate — probably were operative to only a slight extent at most. Their evolutionary pattern would therefore have conformed more closely with that of non-hominids, and ordinary mammalian taxonomic standards would apply to them but not so well to euhominids.

The full extent of the australopithecine material available for study is not generally appreciated. The material from Swartkrans represents a minimum of 35 individuals judging by the more complete specimens. The Sterkfontein collection represents a minimum of 21 individuals. A single child skull is known from Taungs, while three individuals are represented at Kromdraai and a minimum of 5 at Makapansgat. This gives a minimum of 65 individuals. A large number of isolated teeth and smaller specimens strongly suggest that remains from over 100 individuals are now known. From

a paleontological point of view the available sample is therefore a very good one.

The australopithecines are commonly regarded as a small, variable group known only from South Africa. Those who are inclined to the view that the group is ancestral to the euhominids look upon them as a transitional group, all belonging to one species which is variable because in the throes of change from a pongid grade of organization to that of a hominid one. From this point of view any apparent taxonomic distinction between specimens from different sites merely represents the results of the species being split into isolated or semi-isolated breeding groups so that the differences are of very low phyletic valence.

In several recent papers I have presented evidence (Robinson, '53a and b) showing that they were, at the time the known form lived, an old and widespread group. In a further paper (Robinson, '52) their geological age is discussed. This evidence is not compatible with their being either a small, variable and transitional group or a purely South African offshoot of the main hominid line.

CLASSIFICATION OF THE SOUTH AFRICAN FORMS

The correct classification of the South African forms is complicated by the small number of specimens from Taungs, Kromdraai and Makapan. However all the specimens appear to fall clearly into two main groups. It is convenient to compare the samples from Swartkrans and Sterkfontein first, after which the smaller samples from the other sites may be considered. For the sake of convenience the Sterkfontein sample will be regarded as representative of "group A" and the Swartkrans sample of "group B."

One of the most useful characters separating the two groups is the structure of dm_1 . The two types of tooth are illustrated in figure 1. The type belonging to group B, of which there are 6 specimens from 4 mandibles, is a fully molariform tooth with 5 well developed cusps. The tooth is very much like an ordinary permanent lower molar. The cusps are all

closely applied to each other and a well defined, transverse anterior fovea is present. The mesial buccal groove is deeply incised and ends abruptly, sometimes terminated by a small tubercle — a feature characteristic of the permanent molars of the Swartkrans form. The width across the posterior half of the tooth is greater than that across the anterior half, e.g., in SK 64 (least worn tooth) the anterior breadth is

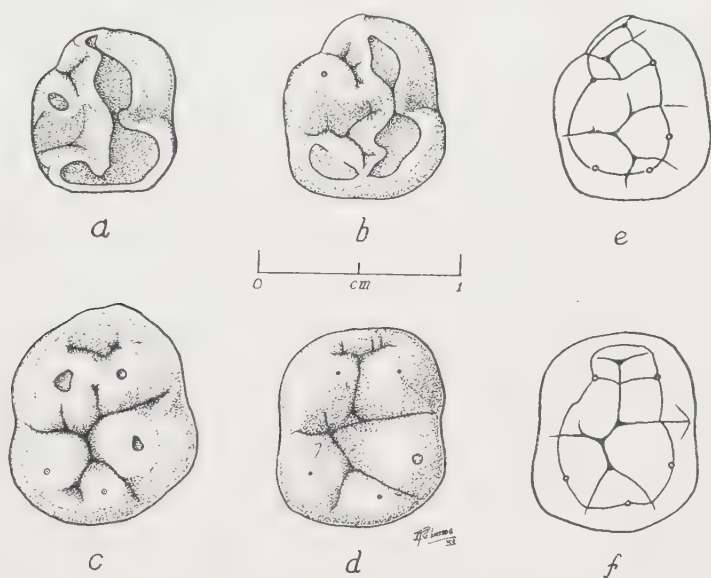


Fig. 1 First lower deciduous molar from (a) Sterkfontein, (b) Taung, (c) Swartkrans and (d) Kromdraai. The first two belong to group A and this tooth type is represented in (e). The second two belong to group B and this tooth type is represented in (f).

7.9 mm while the posterior one is 8.7 mm. On the buccal face the enamel line is approximately horizontal.

The group A form of this tooth is very distinct in appearance. The tooth is smaller than that of group B and is essentially 5-cusped, though the hypoconulid is very small. The entoconid is a small cusp well separated from the protoconid which is sharp and not as well developed as in group B. The major cusp is the metaconid which is well developed and its apex is situated almost on the longitudinal

midline of the tooth. In group B the cusps are of approximately equal size except for the smaller hypoconulid. Here the protoconid and hypoconid are the largest cusps and are subequal. In the group A tooth the anterior fovea is a large depressed area lingual to the metaconid. The latter cusp has a large, sloping buccal face which results in the enamel line being much lower down below this cusp than it is below the hypoconid. The width across the anterior half of the tooth is slightly greater than that across the posterior half.

Unfortunately only one intact specimen of this tooth is known from Sterkfontein but the Taungs child has the same type. Furthermore this tooth form is very similar indeed

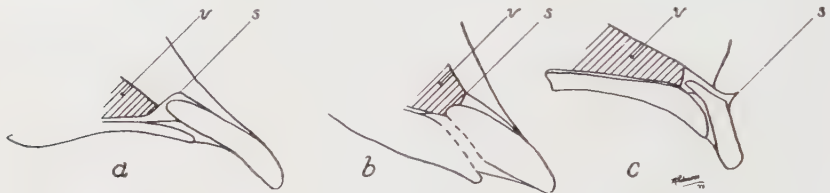


Fig. 2 Sagittal section through the palates of the ape-man from Sterkfontein (a) and Swartkrans (b) and that of a modern Bushman (c). The vomer, V, is shaded and S indicates the anterior nasal spine. The condition in *Telanthropus* resembles that depicted in (c).

to that characteristic of euhominids. The group A and B tooth types are so very different that they can be distinguished at a glance.

A second feature which distinguishes clearly between the two groups is the structure of the anterior part of the nasal cavity floor. In group B the facial plane of the maxillae passes smoothly into the pyriform aperture without any sharp demarcation. There is a small anterior nasal spine in the form of a small roughened area with an apex which points upward and backward. The area surrounding the spine is depressed so that the latter is not visible in lateral view. The anterior extremity of the vomer inserts into a small cleft in back of the anterior nasal spine. In group A there is also no sharp line of demarcation between the lower

margin of the pyriform aperture and the facial plane of the maxillae — as there is in *Telanthropus* and euhominids — but the distinction between the two is nevertheless considerably clearer than it is in group B. The anterior nasal spine is smaller than in the latter group and is sometimes divided into two by a groove for the septal cartilage. The vomer does not insert directly against the back of the spine but inserts in an equivalent position lower down. There is thus a sharp slope from the back of the anterior nasal spine a short distance down to the anterior end of the vomer.



Fig. 3 Transverse sections through the roots of P^3 of (a) the Swartkrans form and (b) the Sterkfontein form. The sections were taken at a point a third of the root length from the apex.

A third feature separating the two groups is the nature of the roots of P^3 . It seems clear that early hominids had three-rooted upper first premolars, and the evolutionary tendency is toward a condition where only a single root is present. In one specimen from Sterkfontein a single root is present but in all other known australopithecine specimens there are at least two roots. Of 13 Sterkfontein specimens only one has a double buccal root, i.e., three roots altogether, while of 19 Swartkrans specimens 14 have double buccal roots. This difference takes on even greater significance when it is remembered that the geologically older form is the more advanced in this respect.

Another point of difference between the two groups is in the size and structure of the canines. In group B upper and

lower canines are small, often being easily matched in both size and structure among the homologues of modern euhominids. There is a clear distinction between the upper and lower canines in structure. In the maxillary tooth the lingual grooves converge sharply onto the gingival eminence and the borders lateral to the grooves are thickened. In the mandibular tooth the thickened borders are not present and the lingual grooves do not meet on the gingival eminence. The crown is slightly asymmetrical in that the cingulum extends higher up the distal face of the crown than it does on the mesial. This feature is not strongly developed, is not present in the upper canine and is also detectable in the mandibular canine of modern euhominids. The canines of group B therefore have a remarkably modern euhominid appearance. Those of group A on the other hand are larger and exhibit some exaggerated features not met with in euhominids. The maxillary canine is robust, symmetrical and has the lingual grooves roughly parallel and without the swollen marginal ridge of group B. These differences are easily seen and no example of this group B type tooth has been seen in a group A specimen. Except for size the structure of this tooth is more easily found among euhominids—even the size is duplicated in *Pithecanthropus*—than is that of group B. However the mandibular canine is markedly different from the group B type. The crown asymmetry is very evident, as can be seen from the illustration (fig. 4). The lingual ridge is always present and, except for one instance (fig. 4c) is very strongly developed. Although the basic structure of the canines is the same in both groups there is an absolute distinction between them so that one could not mistake the one for the other. There is just about as much difference between a lower canine of group A and one of group B as there is between one of group A and one of modern man.

Skull shape also differs between group A and B. In the former the skull is small, narrow, has a small but unmistakable forehead and the supraorbital torus is not marked, i.e., there

is no platform in the glabella region. In group B the skull is slightly larger, is broad across the ear region, has no real forehead and the supraorbital torus is well developed in the region of the glabella so that a flattened platform is present. There is never more than a small degree of maxillary prognathism and the face is flat and broad. In group A prognathism is sometimes no greater than in the former group but may be marked, as in the case of Sts. 5.

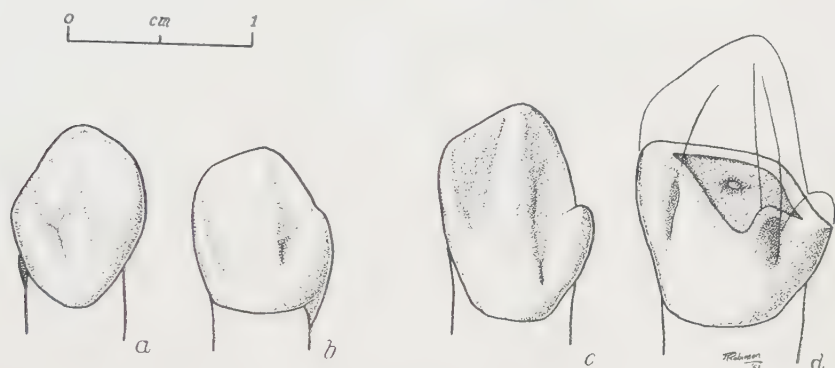


Fig. 4 Australopithecine mandibular canines. (a) SK 96 from Svartkrans. This tooth is from the left side and is the smallest canine in the collection from this site. (b) SK 87, from the right side, is the largest isolated tooth in the collection and has a module of 9.5 while the largest canine known has a module of 9.7. This tooth also is the tooth with the strongest resemblance to the group A type. (c) and (d) are respectively the smallest and largest mandibular canines from Sterkfontein. Both are from the right side. (c) is also the tooth with the least strongly developed lingual ridge. These teeth therefore represent the full range of both size and structure in the known canines of these two groups.

Apart from the more important differences cited above there are others of lesser significance. The crown shape and structure of P_3 differs in the two groups, as does, to a lesser extent, that of P^3 . It appears from the size of the innominates and femurs of the two groups that group A had a body size approximately comparable with that of African pygmies while group B comprised much more robust creatures which were, probably, a bit larger than the average modern man but not large enough to be considered giants. This is mentioned only as a point of interest because comparable size

differences are present in modern man and given no taxonomic significance — though such size differences are often accorded some significance in other animals. Sexual dimorphism is apparently more marked in group A than in group B. In the latter it can be demonstrated, but is manifestly only slight. In the former variation in size and in structure is appreciably greater than in group B and this seems to be associated with a greater degree of sexual dimorphism.

So far this discussion on group A and group B is based only on the Sterkfontein and Swartkrans specimens respectively. It is now necessary to see if and how the other specimens fit into these categories. Starting first with the Kromdraai specimens: these exhibit the dm_1 pattern, crown and roots of P^3 and crown of P_3 typical of group B. All the features of the skull shape cannot be ascertained, but those that are available also are typical of this group. The relations of the vomer and anterior nasal spine are not known but the conformation of the lower part of the pyriform aperture, as far as it is preserved, is of the Swartkrans type. The Kromdraai form fits easily into group B. There are no features which contra-indicate referring it to this group.

The Taungs specimen, being immature, gives information on only a few of the diagnostic features outlined above. However the structure of dm_1 is so obviously like that of group A and so different from that of group B that there can be no question as to which group it belongs. There are no factors inconsistent with its being placed in group A.

The Makapan form requires rather more consideration, not so much because of the nature of the available material but because of the views which have been expressed by Dart and Broom. In my opinion it is indistinguishable from the Sterkfontein form but both Dart (especially '48) and Broom ('50) considered it to differ in a number of points. Broom especially regarded it as so much more advanced than the other australopithecines that he was inclined to give it euhominid status. Dart regarded the occiput from Makapan as belonging to a larger-brained form than that from Sterk-

fontein, the only complete and undistorted skull of which has an endocranial volume of some 480 cm³. On the Makapan occiput the areas for muscle attachment are plainly visible and Dart identified the highest point reached by muscle, in the midline, as the maximum occipital point, with the inion some distance below it. Orienting the skull fragment on this assumption gave a horizontal occipital plate and a contour that could only have belonged to a fairly large skull. It seems to me, however, that if one assumes the maximum occipital

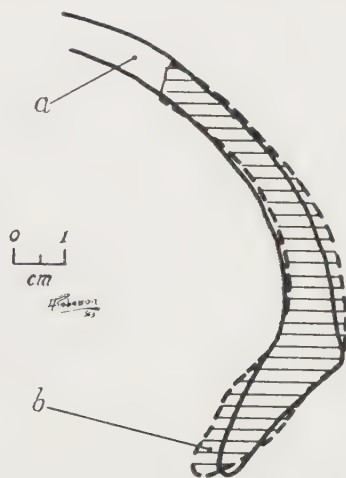


Fig. 5 Comparison of sagittal sections of the occiputs from Sterkfontein and Makapan. (a) section of occiput of Sts. 5, (b) section of the original specimen from Makapan.

point to coincide with the point identified by Dart as the inion, then this occiput is virtually indistinguishable from that of Sts. 5 from Sterkfontein. Both specimens have an unmistakable occipital torus which is situated in an almost identical position in both specimens. The slight overlap of muscle markings over this, in the Makapan specimen, is not uncommon in modern man. In none of the Sterkfontein specimens is the outer table of the skull sufficiently well preserved in this region to show muscle markings. If a sagittal section of the Makapan occiput is superposed over one of Sts. 5 the fit is almost exact (see fig. 5). No special signifi-

cance need be attached to the complicated system of sutural bones in the Makapan occiput, as a mark of taxonomic distinction from other forms, because this is a very variable feature in hominids and the second calvarial fragment from Makapan does not have it.

Broom was particularly impressed by the differences in the innominate from Makapan and that from Sterkfontein, more especially in the structure of the ischium. The Sterkfontein innominate is that of an adult while the Makapan one belonged to an adolescent in which the three elements of the bone had not yet fused. The ilium of the latter is almost exactly like that from Sterkfontein in size and structure. When adult this ilium would have been a little larger than that from Sterkfontein but the difference would have been so small as to be easily explicable as a sexual difference. The ischium, which Broom considered so critical, in my opinion would closely resemble that from Sterkfontein after the remaining small amount of growth had occurred along the acetabular margin and over the ischial tuberosity. There are thus no critical differences between this specimen and that from Sterkfontein in either size or structure.

Unfortunately no dm_1 is known of this form but the single buccal root of P^3 , crown structure of P_3 , and what is known of the lower canine and skull shape and size all mark this form as belonging to group A.

To sum up: on the strength of a series of relatively independent characters the South African australopithecines are here shown to fall into two natural groups, each representing a separate phyletic line. Group A comprises the specimens from Taungs, Sterkfontein and Makapan and group B those from Kromdraai and Swartkrans.

On the strength of some characters of lesser importance subdivisions may be made in both of these groups.

Group B may be divided into two subgroups, one containing the Swartkrans form and the other the specimens from Kromdraai. There are two main reasons for this (a) the structure of the lower deciduous canine and (b) the structure

of the first lower deciduous molar. There is a small size difference between the single Kromdraai specimen of the lower deciduous canine and the 4 Swartkrans specimens, but there certainly was an overlap in their size ranges. The module for the former is 5.0 and the mean module for the latter 5.6. The difference in structure is however much more marked. The Kromdraai canine is an almost symmetrical tooth, in buccal view, with the apex approximately centrally placed and with a very slight distal cusplet. All 4 Swartkrans teeth have markedly asymmetrical crowns with the apex displaced mesially and the distal cusplet large. The difference can

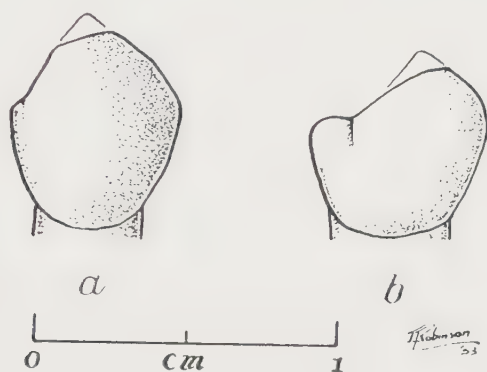


Fig. 6 Comparison right lower deciduous canines from (a) Kromdraai and (b) Swartkrans.

be seen in figure 6. The first lower deciduous molar in all 6 Swartkrans specimens has a distinct mesiobuccal cusplet anterior to the anterior fovea. There is no trace of this on the two Kromdraai teeth (in the same mandible). In the latter specimens the talonid width is the same as the trigonid width whereas in all the Swartkrans specimens the talonid breadth exceeds that of the trigonid. Finally, all specimens (15) of M_1 which are sufficiently unworn have a tuberculum sextum. One other specimen, incompletely erupted, appears to have only a rudiment of this cusp. The partially erupted M_1 of the Kromdraai child mandible has no trace of the 6th tubercle. The adult M_1 is too worn to

allow of certainty but this cusp appears to have been present. This suggests a lower incidence in the Kromdraai form.

Group A may also be divided into two groups. I can find no reason for separating the Sterkfontein and Makapan forms. In practically every feature the variation within the Sterkfontein sample seems sufficient to include the Makapan specimens. The only possible point of difference is the very strongly developed protoconidal cingulum (protostylid) in the Makapan adolescent mandible. However the Sterkfontein M_1 frequently has a protostylid, though not as well developed in any of the specimens known at present. Moreover this feature is known to be very variable and additional Makapan material would almost certainly remove this difference.

The Taungs child does exhibit some features not found in the Sterkfontein specimens. In M_1 of the latter there is no sign of a tuberculum sextum but both specimens of M_1 in the Taungs child have this cusp moderately developed. Furthermore the lower deciduous canine in this form has a distal cusplet but no anterior one whereas in the two Sterkfontein specimens (in the same jaw) there is also an anterior cusp.

It is now necessary to give taxonomic rank to these various groups. The lowest recognized category in zoological nomenclature is the subspecies, and this rank is given to the smaller subdivisions of group A and B. This is arguable from several points of view. In the first place modern mammalian subspecies of the neozoologist are not normally distinguished on skeletal characters. The possibility is therefore real that these smaller groups are in fact species. Furthermore these subspecies are not quite the same as those of neozoology. The Kromdraai apeman may be a direct descendant of the Swartkrans one. The neozoological subspecies are spatially separated while these here suggested are chronologically separated. This matter has been argued by Simpson and others and will not be dealt with in detail here. It seems to me legitimate to make subspecific distinction between closely related, but not identical, forms separated by a time interval.

The reason for making the differences only of subspecific value is several-fold. Although there is abundant material on which to base the major division, at least one of the smaller groups is in each case composed of a small number of specimens, hence one has little idea of its range of variation. Additional material might show that the differences now observed are of specific value or it may confirm the suggested subspecific value. Furthermore the later of these smaller groups may merely be the slightly modified form of the older one, which would decrease the value of the differences.

The two main groups are, on the other hand, on completely separate lines of evolution. Judging by modern mammalian taxonomic standards the amount of difference between them is of considerably greater than specific value and therefore the two groups are here given generic status.

The so-called *Meganthropus africanus* of Weinert, known only from a fragment of maxilla containing P^3 and P^4 , cannot be distinguished from the Sterkfontein apeman (see Robinson, '53) and therefore falls into the same subspecies as the latter on present evidence. As it comes from central Africa it may well be representative of another subspecies or even species. Until further material is available it cannot legitimately be given separate status.

There remains only *Meganthropus palaeojavanicus* to be considered. I have already shown (Robinson, '53a) that this specimen is a typical australopithecine which closely resembles the Swartkrans form. The resemblance is, however, not absolute and there is at least one difference of note. The reduction process, from the front of the tooth row (Robinson, '52b), has progressed further in the Javanese specimen than it has in the South African group B forms. The crown of P_4 is approximately the same size as that of P_3 in the former but larger in the latter specimens. This has been accompanied by a greater degree of root reduction than is present in the South African forms. The mandibular canine which is attributed to this species is appreciably larger (10.0×11.0 mm) than the largest (8.5×8.9 mm) of 9 speci-

mens from Swartkrans. However, in view of the fact that the *Pithecanthropus* maxilla from the Sangiran site (which also yielded the *Meganthropus* specimen) has the largest known prehomimid or euhominid canines, this specimen most probably actually belongs to *Pithecanthropus* and not to *Meganthropus*. Because the differences in P_4 crown and root are of some importance, and the Javanese specimen is separated from the Swartkrans forms by so great a distance geographically, it is unlikely that the differences between them can be of less than specific value.

The prehomimid classification here being presented may be expressed as follows:

- Family: Hominidae
- Subfamily: Australopithecinae
- Genus (1): *Australopithecus*
 - Species: *Africanus africanus* (Taungs)
 - Africanus transvaalensis* (Sterkfontein, Makapan and East Africa)
- Genus (2): *Paranthropus*
 - Species (1): *Robustus robustus* (Kromdraai)
 - Robustus crassidens* (Swartkrans)
 - Species (2): *Palaeojavanicus* (Sangiran)

In this classification the australopithecines are placed in a separate subfamily from euhominids. Mayr's classification requires the australopithecines and euhominids to belong to the same genus and hence automatically to the same subfamily.

It has been shown (Robinson, '53b) that euhominids exhibit some characters not shown by the australopithecines. That is, there is a morphological distinction between an australopithecine and a euhominid grade of organization. Among the more obvious of these differences is the fact that the former group walked erect while the latter not only walked erect but also had a large brain and all that follows from this fact. Furthermore it is clear that the Swartkrans prehomimid could not be ancestral to euhominids because a much more suitable ancestor, *Telanthropus*, lived synchronously with it. The Sterkfontein prehomimid lived slightly

earlier than *Telanthropus* but could not be ancestral to the latter because of certain specializations—for example the later and more advanced *Telanthropus* had a more primitive upper premolar root system, the Sterkfontein form had very specialized canines, etc., and the time interval between them was very short.

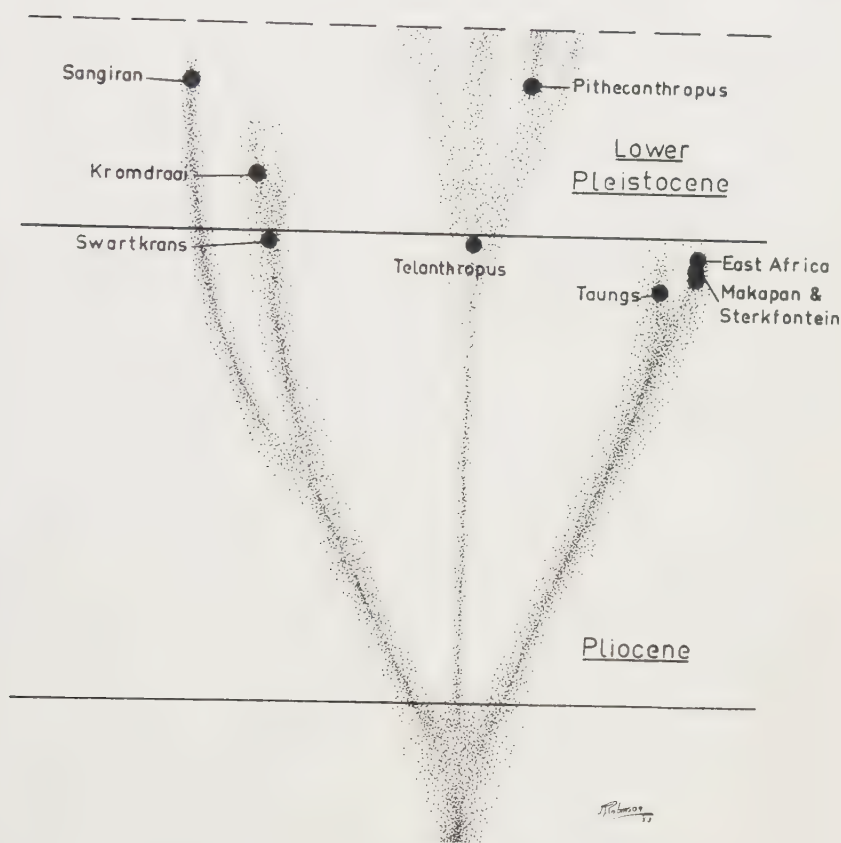


Fig. 7 Suggested evolutionary relationships of the australopithecines, *Telanthropus* and *Pithecanthropus*. The relative lengths of the Lower Pleistocene and the Pliocene are not to scale. The exact position in time of the separation of the three phyletic lines of australopiths is not known, nor is it known whether there were more than three. Probably there were more lines in the early stages of the history of the group. Insufficient material of the Sangiran form is known to judge whether it is nearer the euhominid group than the Swartkrans and Kromdraai forms.

Not only are there morphological distinctions between the prehominids and the euhominids, but it is clear that not all of the former reached the latter grade of organization. Consequently taxonomic distinction between the two groups is required, hence their separation into separate subfamilies.

The genus *Plesianthropus* is sunk, being synonymous with *Australopithecus*, and also *Meganthropus* which is synonymous with *Paranthropus*.

The genera may be defined as follows:

Australopithecus:

dm₁ incompletely molarized, protoconid most strongly developed cusp (including anterior accessory cusplet) with large, sloping buccal face; vomer does not insert directly against back of anterior nasal spine; P³ usually having a single buccal root; canines large with mandibular canine strongly asymmetrical and lingual ridge present, normally strongly developed; skull narrow, forehead present, supraorbital torus not strongly developed.

The specific characters, in this case, are the same, as only one species is known at present.

Subspecies: *Africanus africanus*: tuberculum sextum present on M₁; deciduous canine without mesial cusplet.

Africanus transvaalensis: M₁ without tuberculum sextum; protostylid common and may be large; deciduous canine with mesial cusplet.

Paranthropus:

dm₁ strongly molarized, metaconid and hypoconid largest cusps, protoconid without large, sloping face; vomer does insert against back of anterior nasal spine; P³ usually with double buccal roots; canines small, mandibular one not strongly asymmetrical, lingual ridge never strongly developed; skull broad across ear region, no forehead, supraorbital torus well developed near midline.

Species (1): *Robustus*: crown of P₄ appreciably larger than that of P₃. Root of P₄ double.

Subspecies: *Robustus robustus*: deciduous maxillary canine symmetrical with very small distal cusplet; dm₁ with no mesiobuccal cusplet anterior to anterior fovea.

Robustus crassidens: deciduous lower canine markedly asymmetrical with distal cusp well developed; dm₁ with mesiobuccal cusplet.

Species (2): *Palaeojavanicus*: crowns of P₃ and P₄ subequal; roots of P₄ partially fused.

Telanthropus from Swartkrans has been dealt with at length elsewhere (Robinson, '53b). For this reason and the fact that it is not regarded as a prehominid but a euhominid, it is not discussed here. Its characters are such that it does not fall into either of the genera defined above. It is a product of a third phyletic line of the prehominids, distinct from the above two, of which specimens could only be discovered by finding geologically earlier australopithecine-bearing deposits than those now known. This line must have been a higher-rate line than either of the two others.

CONCLUSIONS

1. The prehominids, by the lower Pleistocene, were a group with a long evolutionary past.
2. The group was not simply a short-lived, highly variable one, transitional between pongids and euhominids.
3. All the known australopithecines fall easily into two genera, *Australopithecus* and *Paranthropus*, each representing a separate line of evolution.
4. *Australopithecus* contains a single species with two subspecies, containing the specimens from Taungs, Sterkfontein, Makapan and East Africa.
5. *Paranthropus* contains two species, one with two subspecies, distinguishing the specimens from Kromdraai and Swartkrans, the other containing the Javanese specimen hitherto referred to as *Meganthropus palaeojavanicus*.
6. *Telanthropus* is a euhominid descended from the prehominids but not from either of the above phyletic lines.
7. The prehominids therefore include at least three phyletic lines of which at least one progressed to the euhominid grade of organization.

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RECONSTRUCTION OF TALGAI DENTAL ARCH.—In August, 1952, the Talgai teeth were measured several times by Dr. T. D. Campbell and the writer independently; the results were averaged. We then re-measured the teeth together and reached agreement on the averaged figures. . . .

Using these revised figures, the writer presents . . . a reconstruction of the Talgai dental arch; it is based on a study of the interproximal attrition. The method evolved consisted of 5-fold enlargement of each tooth; the contours of the interproximal surfaces were fitted together and the total dental arch so arranged was then reduced back to natural size.

The result bears a rather close approximation to that obtained by Hellman. . . .

It seems likely that the rather similar results, obtained by Hellman and the writer, using entirely different methods, must be close to the original state in life.

If this is correct only three extraordinary features are left to the Talgai cranium, i.e., the great size of canine teeth, the great length of palate for a 16-year-old youth, and the great size of the detached central incisor originally measured by Smith and now lost.—N. W. G. MACINTOSH. The Talgai teeth and dental arch: Remeasurement and reconstruction. Oceania, vol. 23, no. 2, Dec., 1952, pp. 106-109

CORRELATION BETWEEN PERFORMANCE AND PHYSIQUE IN FINNISH ATHLETES

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A suitable physique has been considered one of the prerequisites of good performance in athletics. It might be supposed from this that the followers of each branch of athletics should possess the specific constitutional features suiting best the pursuit of that athletic event. In an earlier paper (Telkkä, Pere and Kunnas, '51) the authors investigated this supposition by means of anthropometric studies. The subjects studied comprised 245 Finnish top-ranking athletes, the majority of them track and field athletes (182) and the remainder wrestlers (63). The athletic level of the subjects was high; they had, among them, won 30 gold, 22 silver and 18 bronze medals in the Olympic Games and other contests, in addition to a score of European championships, and several held world records. Measurements obtained on that material led the authors to conclude that —

(1) The followers of different branches of athletics do not differ appreciably as to their constitution, certain extreme groups excepted.

(2) No definite ideal type for a certain athletic event could be ascertained.

(3) Athletes differ slightly in body build from other Finnish men of the same age. Thus we may speak of an "athletic type," although actual constitutional types characteristic of different athletic events cannot be distinguished.

According to that material body build of a definite type did not appear to be a necessary prerequisite to the achievement of good athletic results.

¹ The authors gratefully acknowledge the statistical assistance given them by Dr. Josef Brožek.

In order to throw further light on the question of whether the achievement of good athletic results presupposes a definite physique the present paper examines the matter by correlating performance and certain morphological measurements. In this study the best performance of each athlete has been taken as the standard of performance.

MATERIAL AND METHOD

The subjects studied were track and field athletes grouped as follows:

Jumpers	33
Throwers	45
Sprinters	46
Long-distance runners	48
Total	172

The average age of the athletes examined and their highest and lowest age are stated below:

	JUMPERS	THROWERS	SPRINTERS	LONG-DISTANCE RUNNERS	ALL GROUPS
Average age, years	26.2	29.7	24.7	29.7	27.6
Lowest age	18	19	18	21	18
Highest age	45	38	49	36	49

The measurements of the material were taken according to Martin ('28). They were selected with a view to emphasizing the characteristic build of the athlete, as determined by the following²:

- Stature
- Relative lower limb length
- Relative upper limb length
- Relative trunk length
- Relative shoulder breadth
- Relative hip width
- Relative chest circumference
- Relative thigh circumference

² Correlation between weight and performance has not been presented because some of the athletes were measured during the competition period, some of them during the rest period.

Using the correlation coefficient the physical measurements thus obtained have been compared with the athletic achievements of each athlete converted into points according to the International Scoring Table (Ohls) from 1934. In this table each athletic achievement has been awarded a certain number of points, thus making the results obtained in different athletic events comparable as far as possible.

The correlation coefficient, r , has been calculated from the following formula:

$$r_{xy} = \frac{\sum \Delta_x \cdot \Delta_y}{n \cdot \sigma_x \cdot \sigma_y}$$

where Δ_x and Δ_y are the individual deviations from the means, and σ_x and σ_y the respective standard deviations, and n the number of observations.

The significance of the correlation coefficient is determined by the values of t , calculated from the formula $t = \frac{r}{\sqrt{1-r^2}} \cdot \sqrt{n-2}$.

The values of the correlation coefficients required for the significance have been determined according to Lindquist ('40). If above the 1% level, t is marked by ++, between 1 and 5% by +, and below 5% by —.

As far as correlation treatment is concerned, this kind of series chosen out of top-class athletes, in which the variation of athletic performance is small, theoretically is not the best possible. Yet, in practice there are certain limits to obtaining control series of athletes who have participated in sports for long periods without having obtained good records.

RESULTS

Table 1 shows the means, σ , and the values of r with their significance.

Stature. Throwers are the tallest, on the average, of Finnish track and field athletes, 180.8 cm, but also the average height of jumpers (178.3 cm) and runners (sprinters 177.4 cm, long-distance runners 172.2 cm) clearly exceeds the average Finnish male height, 168.9 cm (Pesonen, '36). The correla-

TABLE 1

Correlations between relative measurements and athletic performance

	SPRINTERS (N = 46)						LONG-DISTANCE RUNNERS (N = 48)					
	Mean	σ	r	t	Signifi- cance		Mean	σ	r	t	Signifi- cance	
Stature	177.4	5.93	+ .31	2.162	+		172.2	6.17	+ .04	.271	—	
Relative lower limb length	53.4	1.19	+ .02	.133	—		53.7	1.38	+ .11	.751	—	
Relative upper limb length	44.1	1.38	+ .09	.597	—		44.8	1.57	+ .28	1.979	+	
Relative trunk length	30.4	1.22	+ .05	.332	—		30.4	1.46	— .12	.820	—	
Relative shoulder breadth	21.6	1.16	+ .03	.199	—		21.9	1.14	— .22	1.530	—	
Relative hip width	16.5	.84	+ .01	.066	—		16.7	.87	— .12	.820	—	
Relative chest circumference	51.9	2.49	— .42	3.070	++		52.5	2.10	+ .15	1.029	—	
Relative thigh circumference	30.0	1.73	— .30	2.086	+		29.2	1.30	+ .18	1.241	—	
Relative upper arm circum- ference												
Points (Ohls, '34)	885	74.33					986	85.96				
	JUMPERS (N = 33)						THROWERS (N = 45)					
	Mean	σ	r	t	Signifi- cance		Mean	σ	r	t	Signifi- cance	
Stature	178.3	5.25	+ .24	1.376	—		180.8	5.52	+ .39	2.777	++	
Relative lower limb length	53.4	1.21	+ .15	.845	—		53.3	1.33	+ .01	.066	—	
Relative upper limb length	43.9	1.54	+ .21	1.196	—		44.1	1.59	+ .34	2.370	+	
Relative trunk length	30.5	1.10	— .01	.056	—		30.7	1.40	+ .04	.262	—	
Relative shoulder breadth	22.0	.97	— .23	1.316	—		22.5	1.10	— .50	3.786	++	
Relative hip width	16.2	.84	— .22	1.256	—		17.2	.81	— .01	.066	—	
Relative chest circumference	51.7	2.38	— .32	1.881	—		55.0	2.71	+ .37	2.612	+	
Relative thigh circumference	30.3	1.34	— .11	.616	—		32.3	1.63	+ .09	.590	—	
Relative upper arm circum- ference												
Points (Ohls, '34)	885	93.26					917	120.49				

tion between height and performance is highly significant in the thrower group and significant in the sprinter group, whereas no correlation can be shown in the other two groups.

Relative lower limb length. Correlation between relative lower limb length and performance is not found in any group.

Relative upper limb length. The correlation between performance and relative upper limb length was significant in the long-distance runners' group only.

Relative trunk length and relative hip width. No correlation between performance and these characteristics was established in any athletic group.

Relative shoulder breadth. The correlation between performance and relative shoulder breadth was negative and highly significant in the thrower group. Correlation was not ascertained in other groups.

Relative chest circumference. The correlation between performance and relative chest circumference was positive and significant for the thrower group, while it was negative and highly significant for the sprinters.

Relative thigh circumference and upper arm circumference. The correlation between performance and relative thigh circumference is negative and significant in the sprinter group, whereas no correlation was found in the other three groups. Neither was there any correlation of the performance and the upper circumference, which was calculated for the thrower group only.

DISCUSSION

This study has endeavored to throw light on the relationship of form to function by means of correlation calculations. Measurements of the participants in different forms of athletic event have been taken as the starting point and compared with the best performance of these athletes. The material has been selected from first-class athletes who have been active in their respective athletic fields for several years. One would thus suppose them to possess the specific constitutional features which are characteristic of the competitors in their particular field. For the comparison of physique and

performance we have taken each athlete's best achievement as the standard of performance. The athletic ability may be regarded as the sum of all the different factors by means of which this achievement is brought about. The joint effect of these factors is not brought out with anywhere near the same degree of accuracy by different functional tests.

Earlier literature attaches great importance to physical constitution in deliberating the origination of good athletic achievements (Kohlrausch, '29; Herxheimer, '33; Saller, '30; Jaensch and Hoffmann, '37; Parnell, '51). Investigations of more recent date do not attach such great significance to physique (Vandervael, '46; Bøje, '42; Telkkä, Pere and Kunnas, '51; Cureton, '51), emphasizing also the effect of other factors in the achievement of good results. Tappen ('50) has investigated the relation of performance to morphological measurements of championship weight lifters, obtaining high correlations between weight and height and performance. On the other hand, the correlations between different skeletal indices and performance were low.

In the present material throwers constituted the tallest group, and they were definitely taller than the average Finnish male. On the basis of the correlation observed great height must be considered as an advantage in throwing events. This is also indicated by the fact that all the throwers chosen for this study were above the mean for Finnish male height. Kohlrausch ('29) found the same to be true of the participants in the Olympic Games at Amsterdam: that throwers were generally the tallest of all the track and field athletes. Cureton ('51) too regards great height as an advantage in throwing events.

According to the properties studied, the length of the lower limbs does not seem to be of great importance, no correlation having been observed in any group. On the other hand, throwers seem to benefit most from the relative length of the upper limbs. Consequently, the lengthening of the "lever arm" obviously improves the throwing performance. Karvonen and Kunnas ('47) have studied the arm length of Fin-

nish lumbermen and have found in that case also that the long-armed men have the best working performance.

The highly significant and negative correlation between the shoulder breadth and performance is prominent. In addition, the relative shoulder breadth of the throwers achieving the best results was below the mean of this group, which seems to indicate that very broad shoulders may be considered as a disadvantage for good throwers.

The correlation between chest circumference and performance was clearly negative in sprinters, indicating in the first place their fairly small respiratory requirement and comparatively light build.

The results would seem to indicate that individual constitutional features have no decisive bearing on performance as, with the exception of a few cases, their intercorrelations were generally low. These observations conform well with the opinion reached by the writers from the anthropometric examination of athletes: the representatives of different branches of track and field athletics do not differ noticeably, apart from some extreme groups, from each other as regards the average measurements of each group. As far as different types are concerned, representing the various forms of athletics, it seemed from the anthropometric studies made that they did not exist in our material. The small number of correlations obtained between performance and constitutional features in the subjects studied could indicate that high achievement in a given field of athletics can be reached by athletes of very different physique.

SUMMARY

The present paper examines the correlations between the performance and the physique of Finnish track and field athletes. The subjects used for the study were 172 track and field athletes selected from top-ranking sportsmen. The best athletic achievements of each athlete were used as the standard, converted into points according to the International Scoring Table. The achievements in different events are then comparable to each other. The main results are given below:

(1) Throwers were the tallest in this material and they seemed also to benefit most from their height.

(2) The correlation between relative upper limb length and performance was significant in throwers and long distance runners.

(3) The correlation between relative shoulder breadth and performance was negative and highly significant in throwers.

(4) The correlation between relative chest circumference and performance was negative and highly significant in sprinters and positive and significant in throwers.

The correlations between the measures taken of our subjects and the corresponding athletic abilities are few and thus could indicate that the physique does not affect the athletic performance.

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SOMATOTYPING BY PHYSICAL ANTHROPOMETRY

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TWO FIGURES

In 1940 Sheldon, Stevens and Tucker introduced their method of somatotyping by inspection of standard photographs. Their work has provided an immense stimulus to anthropologists. While fully recognizing the great value of this contribution there are certain practical difficulties which have hindered the more general adoption of their method. Among these difficulties are the following:

1. Standards of somatotype dominance are subjectively determined. This means that where the metric method is used and the labor of taking 17 photographic measurements, calculating the corresponding ratio indices and looking up the most fitting somatotype in tables has been correctly completed, the result may still be wrong if the original choice of dominance was incorrect. It is believed that the long metric method of typing recommended in "Varieties of Human Physique" by Sheldon and his colleagues has largely fallen into disuse and this is no doubt partly due to the great deal

¹I am most grateful to my personal assistants, to Mrs. C. C. Standley who measured most of the photographs and carried out the photometric typing according to my photoscopic estimates, and to Mrs. S. C. McIntosh for statistical help especially in compiling the deviation tables. Dr. J. M. Tanner introduced me to somatotyping and himself measured and photographed many of the Oxford undergraduates. Dr. R. H. Bolton, Senior University Medical Officer, kindly granted me permission to carry out the anthropometric survey of first year students at Birmingham in the course of their routine overhaul. The first part of the work was undertaken while I was Student Health Physician at the Institute of Social Medicine, Oxford, the latter part while in receipt of a further grant from the Nuffield Foundation to undertake research in the constitutional aspects of psychiatric medicine at the Warneford Hospital, Oxford.

of labor involved, amounting in my experience to not less than one hour's work for each subject. If this is so then an important prop of objectivity has been removed and there remains insufficient guarantee against shifting standards of rating. In due course a more complete reference book of somatotype photographs may become available for general use. This will help, but agreement as to a given somatotype will still depend on personal interpretation of visual impressions, not upon measurement. If somatotypers agree it will mean that they have learnt to sing in harmony, but their song does not thereby become a science, it remains an art. Sheldon, Hartl and McDermott ('51) emphasize the skill required in anthroposcopic somatotyping and say "somatotyping cannot begin and end with millimeters." It is agreed that the photographic record provides information in more assimilable form than any large number of bare measurements, therefore somatotyping cannot end with millimeters, but it may reasonably begin with measurement and it is hoped to show here that physical anthropometry can provide a useful degree of scientific objectivity as a preliminary guide to somatotypists, though inspection of the photograph may lead to some slight subsequent revision of this preliminary estimate.

2. The second difficulty is that objection to being photographed in the nude may render the somatotyped sample unrepresentative of a population chosen for study. This applies more particularly in somatotyping women.

3. A third difficulty not infrequently encountered is to find accommodation for the 10 meter camera-subject distance recommended by Tanner and Weiner together with the cost of photographic equipment, development and standard enlargement of photographs.

The purpose of this paper is to describe a short physical anthropometric method, which can be used during clinical interview for the following purposes:

(a) To provide objective guidance as to dominance of somatotype in healthy persons.

(b) To estimate the Sheldonian somatotype objectively and as accurately at least as the agreement achieved between experts at photoscopic somatotyping.

(c) To make an estimate of women's somatotype possible although in the absence of a published reference file of photographs this estimate cannot yet be checked by photoscopic standards.

(d) To reduce the cost, labor, delay and other handicaps inherent in photometric methods.

DEVIATION CHART PROFILE OF PHYSIQUE

The method of estimating dominance depends primarily on what will be described as the Standard Deviation Chart. On this chart (see table 1) standard scales are shown for height, weight, height/ $\sqrt[3]{\text{weight}}$ (hereinafter referred to as the ponderal index), for two bone sizes, the bicondylar measurements of humerus and femur, for two muscle girths, namely that over the tensed biceps with fully flexed elbow and the calf girth standing, and lastly for three skinfold measurements of subcutaneous fat and the total of these three fat measurements. A discriminant function scale of androgyny as described by Tanner ('51) is also included but this is of secondary importance for estimating somatotype. Subsidiary scales are used also for biacromial measurement, bi-iliac, chest width and chest depth, but these too are of secondary importance for the main purpose, though they serve at times to provide useful supplementary evidence.

The scales were each plotted around the mean value, with one column unit equivalent to one-half standard deviation, giving a 13-point scale over all.² The necessary measurements occupy about 5 minutes in the taking and by ringing the appropriate measurement for a given person on the deviation

² These are "extensive" scales which differ in certain respects from the "equal appearing interval" scales used in somatotyping. See "Varieties of Human Physique," p. 115. Note that the scales are extended in the minus direction beyond the "—3" line; this is to cover the range of female values, and the female means are shown in boxes.

TABLE 1

Deviation chart of physique

	Name										Age		Ref. no.		Somatotype				
	-5	-4½	-4	-3½	-3	-2½	-2	-1½	-1	-½	MEAN	+½	+1	+1½	+2	+2½	+3		
STANDARD SCALE																			
Height (ins.)	57.5	58.8	60.1	61.4	62.6	63.8	65.0	66.3	67.5	68.8	70	71.2	72.4	73.6	74.9	76.1	77.3		
Weight (lbs.)	60	69	78	87	96	105	114	123	132	141	150	158	167	176	185	193	202		
H.W. Ratio	10.5	10.75	11.0	11.3	11.6	11.8	12.1	12.4	12.6	12.9	13.2	13.5	13.7	14.0	14.3	14.5	14.8		
Bone: Humerus (cm)	5.0	5.2	5.4	5.56	5.74	5.9	6.1	6.3	6.4	6.6	6.8	7.0	7.1	7.3	7.5	7.7	7.8		
Femur (cm)	7.7	7.9	8.1	8.3	8.5	8.7	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9		
Muscle: Biceps (cm)	19.8	20.9	22.0	23.2	24.3	25.4	26.5	27.6	28.7	29.9	31.0	32.1	33.2	34.3	35.4	36.5	37.6		
Calf (cm)	26.2	27.2	28.2	29.2	30.2	31.2	32.3	33.3	34.3	35.3	36.3	37.3	38.3	39.4	40.4	41.4	42.4		
Fat: Subcut. subscapular (mm)					5.0	6.0	7.0	8.5	10.5	12.5	15.0	18.0	21.5	26.0	31.0	38.0	+		
Subcut. suprailiac					3.0	4.0	5.0	6.5	8.0	10.0	12.0	15.0	19.0	23.0	28.0	35.0	+		
Subcut. over triceps					3.5	4.5	5.0	6.0	7.5	9.0	10.5	12.5	15.0	18.0	21.0	25.0	30.0		
Total of 3 subcut. (T.F.)					12	14	17	20	24	29	35	42	50	60	72	87	104		
Androgyny: 3 Biae — Bi-iliac	66.4	68.8	71.2	73.5	75.9	78.3	80.6	83.0	85.4	87.8	90.1	92.5	94.8	97.2	99.6	102.0	104.3		
Biacromial (cm)	30.7	31.6	32.4	33.3	34.2	35.1	36.0	36.9	37.7	38.6	39.5	40.4	41.3	42.2	43.0	43.9	44.8		
Bi-iliac (cm)				23.0	23.8	24.6	25.4	26.2	27.0	27.8	28.6	29.4	30.2	31.0	31.8	32.6	33.4		
Chest width (cm)		20.3	21.2	22.0	22.9	23.8	24.7	25.6	26.4	27.3	28.5	29.0	29.8	30.7	31.5	32.4	33.3		
Chest depth (cm)			13.9	14.7	15.6	16.3	17.1	18.0	18.9	19.7	20.6	21.5	22.3	23.2	24.0	24.8	25.6		
H.W. Ratio					12.2	12.3	12.5	12.7	12.9	13.1	13.2	13.4	13.6	13.8	14.0	14.2	14.4		
					or less	12.4	12.6	12.8	13.0		13.3	13.5	13.7	13.9	14.1	14.3	+		
Provisional estimate Ectomorphy at ages 16-20 yrs.					1	1½	2	2½	3	3½	3½ or 4	4½	5	5½	6	6½	7		
Provisional estimate Endomorphy from T.F. column above					1.0	1.5	2.3	3.0	3.2	3.5	3.8	4.1	4.75	5.4	6.1	6.5	7.0		
Column code	8	8½	9	9½	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7		

chart, a profile is outlined which reveals the main physical characteristics at a glance. The profile may be read on sight and an opinion formed as to somatotype dominance. Armed with this and Sheldon's somatotype table for each ponderal index, a fairly accurate estimate of somatotype may be obtained, and there is the distinct advantage that the chart may be employed to provide an estimate of somatotype during the clinical interview.

For subsequent more exact quantification or to guide beginners in interpretation of the profile, a set of tables is supplied in the appendix which give estimates of the direction of endomorphic-mesomorphic dominance corresponding to each bone and girth measurement, for each height and ponderal index. These tables were derived from the measurements of 405 undergraduates at Oxford, 1948 to 1951, and 508 first year students at Birmingham, 1952. When constructing the tables, age limits were set from 17 to 24 years inclusive. The Oxford series had been somatotyped using Sheldon's long photometric method; in addition 283 had also been independently typed photoscopically (78 of them by Dr. C. W. Dupertuis) as reported elsewhere by Tanner ('52).

VALIDITY OF RESULTS

Deviation table typing compared with the photometric method

Estimates of somatotype obtained by physical anthropometry have been compared with results obtained using Sheldon's long photometric method. For this comparison only men aged 16-20 have been included according to the limits within which Sheldon's tables were standardized. There were 154 men of that age and table 2 summarizes the differences. A plus sign implies that deviation table ratings were higher.

It will be seen that in 90.0% of cases ratings were correct to half a unit. This compares well with the agreement between experts using the photoscopic method (Tanner, '52).

That the agreement is not actually closer could be due in part to incorrect photometric typing, since the essential preliminary photoscopic estimates of dominance might have been wrong.

TABLE 2

Amounts by which deviation table estimates of 154 Oxford men differed from ratings based on Sheldon's photometric tables

DIFFERENCES	-1½	-1	-½	0	+½	+1	MEAN DIFFERENCE
Endomorphy	1	11	58	57	23	4	-0.169
Mesomorphy	1	17	40	59	32	5	-0.075
Ectomorphy	0	2	27	81	39	5	+0.058
Total no. ratings	2	30	125	197	94	14	462
Total per cent	0.4	6.5	27.1	42.6	20.3	3.0	99.9

TABLE 3

Differences between deviation table estimates and photoscopic ratings in 282 Oxford men

DIFFERENCES	-1½	-1	-½	0	+½	+1	+1½	MEAN DIFFERENCE
Endomorphy	1	25	82	97	64	12	1	-0.08
Mesomorphy	0	7	44	95	98	32	6	+0.22
Ectomorphy	0	10	55	146	57	13	1	+0.02
Total no. ratings	1	42	181	338	219	57	8	846
Total per cent	0.1	4.9	21.4	40.0	25.9	6.7	1.0	100.0

Deviation table typing compared with anthroposcopy

Deviation table estimates have also been compared with photoscopic ratings (see table 3). The subjects for this comparison numbered 282 from the series of Oxford undergraduates reported by Tanner ('52).

It will be seen that in 87.3% of cases the ratings were correct to half a unit. There was a tendency, however, in the photoscopic method to rate mesomorphy lower by roughly one-fifth of a unit.

DETAILS OF THE METHOD

Construction of the standard scales on the deviation chart was straightforward where the frequency distribution was sufficiently natural or Gaussian in shape. This was generally so, but there were two exceptions. The ponderal index distribution showed some skewness. Though this ratio correlates very closely with ectomorphy the standard scale does not correspond precisely with Sheldon's scale of ectomorphy and in order to make a provisional estimate of ectomorphy from the ponderal index corresponding values are included in the lowest section of the deviation chart. The values are derived from table 23 in "Varieties of Human Physique" and a provisional estimate may be expected in young men aged 16 to 20 to be within plus or minus half a point of the true value, with only rare exceptions where the provisional estimate may be as much as one unit out. The skinfold measurements of subcutaneous fat also showed a skewed distribution. To relieve the skewness fat measurements were converted to logarithmic scales and the same thing was done with the total of the three fat measurements. Once the scale had been constructed, however, the appropriate number could be ringed as for the other individual measurements and no reference to logarithmic tables is necessary when using the deviation chart.

Method of taking the measurements

Height was recorded in inches. The subject stands back to a wall scale, takes a deep breath and stretches up to maximal height, his heels remaining in contact with the ground.

Weight is recorded to the nearest pound, for the Oxford series this was without clothes, for the Birmingham series a pair of pants and socks were permitted, weight approximately 8 oz.

Bone measurements (in centimeters). The distance between median and lateral epicondyles of the humerus was taken and secondly the distance between median and lateral epicondyles of the femur. Engineers' steel calipers fitted with

Vernier scale were used for the femur but ordinary steel outside curved calipers fitted with screw adjustment do equally well and are preferable for the elbow. The points of the calipers with the measurer's index finger alongside are placed firmly against the tips of each epicondyle and the subject himself tightens the screw. A steel centimeter rule allows the distance between caliper points to be measured to 0.5 mm. The caliper points are slightly blunted with a file and the skin is eased away with the forefinger to prevent scratching when the calipers are removed. Alternatively the split screw may be released half a turn while the calipers are withdrawn and subsequently tightened by the same amount.

Muscle girth measurements (in centimeters). Biceps girth was taken with a highly flexible steel tape in light contact with the skin over a tensely contracted biceps with the elbow fully flexed. Calf girth taken with the subject standing erect, the legs almost touching and the tape in light contact with the skin. The maximal girth was recorded.

Skinfold measurements of subcutaneous fat (in millimeters) were recorded with modified Franzen subcutaneous tissue calipers at three sites:

1. *Subscapular*. The skinfold was raised with the thumb and forefinger of the left hand over the angle of the scapula, the skinfold running downwards in the direction of the ribs. The subject's arm hangs by his side. The skinfold should not be held too tightly because it is tender when pinched.

2. *Suprailiac*. The skinfold is raised as before with the left hand in a position one to two inches above the anterior superior iliac spine, and the fold is raised so that it runs in the direction of the intercostal nerves.

3. *Over triceps muscle*. Halfway between the acromion and the olecranon on the posterior aspect of the arm. Care was taken to make sure no muscle fibers were included; in case of doubt if the subject locks his elbow momentarily the muscle fibers will withdraw from the fold. The elbow should not be held locked for this partly tethers the skin.

Biacromial width (centimeters). For this it is important to make certain that the shoulder muscles are relaxed and that the shoulder girdle is not braced back or upwards, neither should the shoulders be rounded too far forward. Comparison of the results obtained using a pelvimeter and an anthropometer showed that the pelvimeter with its diminished scale was not a fully satisfactory instrument. A suitable instrument has been made at very moderate cost by fitting arms to a standard 50 cm steel rule. The arms are pressed firmly against the outer aspect of each acromial process.

Bi-iliac width (centimeters) is taken between the outer aspects of the iliac crest using firm pressure against the bone.

TABLE 4

Correlation coefficients between individual skinfold measurements and the sum of all three

	410 OXFORD MEN AGED 17-24	164 OXFORD WOMEN AGED 17-23
Total fat and subscapular fat	$r = 0.97$	$r = 0.82$
Total fat and suprailiac fat	$r = 0.93$	$r = 0.81$
Total fat and triceps region fat	$r = 0.84$	$r = 0.82$

Chest width and chest depth (centimeters) were taken with the thorax midway between full inspiration and expiration. The arms of the pelvimeter were held horizontally level with the greatest width or depth. This level varied quite widely. Anatomical precision was foregone with the object of indicating the relationship between maximal antero-posterior and maximal lateral development of the thorax.

*The three fat measurements as an indication
of the total subcutaneous fat*

It is necessary to consider how far these three skinfold measurements may be taken to indicate the total amount of subcutaneous fat in the body. The first step taken was to correlate each of the three subcutaneous measurements with the sum of all three. The results are given in table 4. These

results are encouraging and perhaps a little surprising, for it seemed clear after only short clinical experience that sites of adiposity vary to some extent from one individual to another. In order to evaluate the sum of the three fat measurements used in the survey as an indication of general subcutaneous fat in the body it was desirable to correlate this total with totals obtained using a much larger number of measurements.

Edwards ('50) published interesting observations on the distribution of subcutaneous fat. He had measured 53 sites including the three used in this survey and he has been kind enough to allow me to use his measurements. Edwards' subjects were 24 obese women but 48 sets of measurements were used since each person was measured before and after 28 lbs. or more reduction in weight. The coefficient of correlation between the sum of measurements at 53 sites and the sum at the three sites used in this survey showed very close agreement, 0.99. This high degree of correlation in women, among whom variation of individual measurements is greater than in men, made it possible to proceed with a fair degree of confidence that the sum of the particular three measurements chosen was a fairly good indication of the total subcutaneous fat in the body.

These remarks do not imply that individual variation does not occur in the pattern of fat storage. It was clear in table 4 that in men fat in the region of triceps departed more often from the average pattern. A large amount of fat over the triceps muscle is in fact a feminine feature and in men high fat measurement in this region relative to others suggests gynandromorphy.³ In mesomorphs the fat measurement with the highest standard score is commonly the subscapular one; in endomorphs the supriliac.

The total of the three fat measurements will be used in the deviation chart profile to obtain a provisional estimate

³ In the Oxford series, excluding central somatotypes, 61% of endomorphic-ectomorphs had their highest fat standard score in the triceps region, but among mesomorphs this feature was only present in 22%.

of endomorphy. It is recognized that this ignores other important anatomical characteristics of endomorphs, for example their relatively small bone structure, but this feature is directly visible on the deviation chart.

On the last line of the deviation chart there will be found a provisional estimate of endomorphy corresponding to the total fat score in the same column above it. These provisional estimates represent average endomorphy figures in the Oxford series (photometric ratings) corresponding to the total fat score. The ultimate justification for using total fat measurements as an indication of endomorphy may be judged from the closeness of the final estimates obtained by this method and by expert anthroposcopic typing.

The profiles

The varieties of somatotype dominance are found on Sheldon's chart (fig. 1) on which incidentally the distribution of 405 Oxford men has been plotted, as derived by deviation table typing.

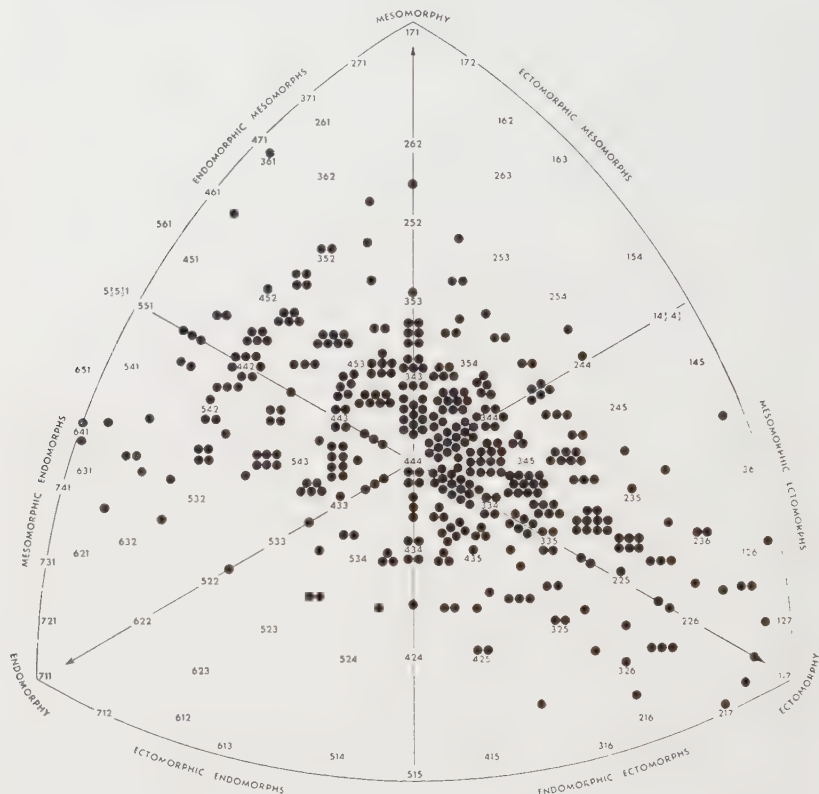
The next step is to describe the main characteristics of profiles corresponding to each somatotype dominance. For a person of about average height, that is for someone whose height lies within approximately three inches of the mean, figure 2 illustrates the relationship between height, bone, muscle girth and subcutaneous fat standard scores.

In the diagram, "B" is taken as the average of the two bone standard scores, "M" is the average of the two muscle girth scores and a cross is used to indicate an average value for bone and muscle development. A straight line has been drawn connecting the height and total fat standard scores.

In endomorphs and endomorphic-mesomorphs this line "HF" lies in the direction of the French "accent grave" (top left to bottom right). This was found to be true of even the tallest endomorphs in the series.

In ectomorphs and ectomorphic-mesomorphs the line "HF" runs in the direction of the French "accent aigu" (top right

to bottom left). The only exception to this is in short ectomorphs but here the ponderal index will save confusion since at this age all ectomorphs, including those with shared primary dominance, have a ratio exceeding 13.25.



A SCHEMATIC TWO-DIMENSIONAL PROJECTION OF THE THEORETICAL SPATIAL RELATIONSHIPS AMONG THE KNOWN SOMATOTYPES

Fig. 1 The somatotype distribution of 405 Oxford men undergraduates.

The line "HF" is vertical in the somatotypes 444 of average height. It is vertical also in endomorph-ectomorphs (434, 424) and primary mesomorphs (343, 353, 262) when secondary dominance is shared.

Primary mesomorphic dominance is present where the "BM" average point marked with a cross lies to the right of both the height standard score "H" and the "HF" line.

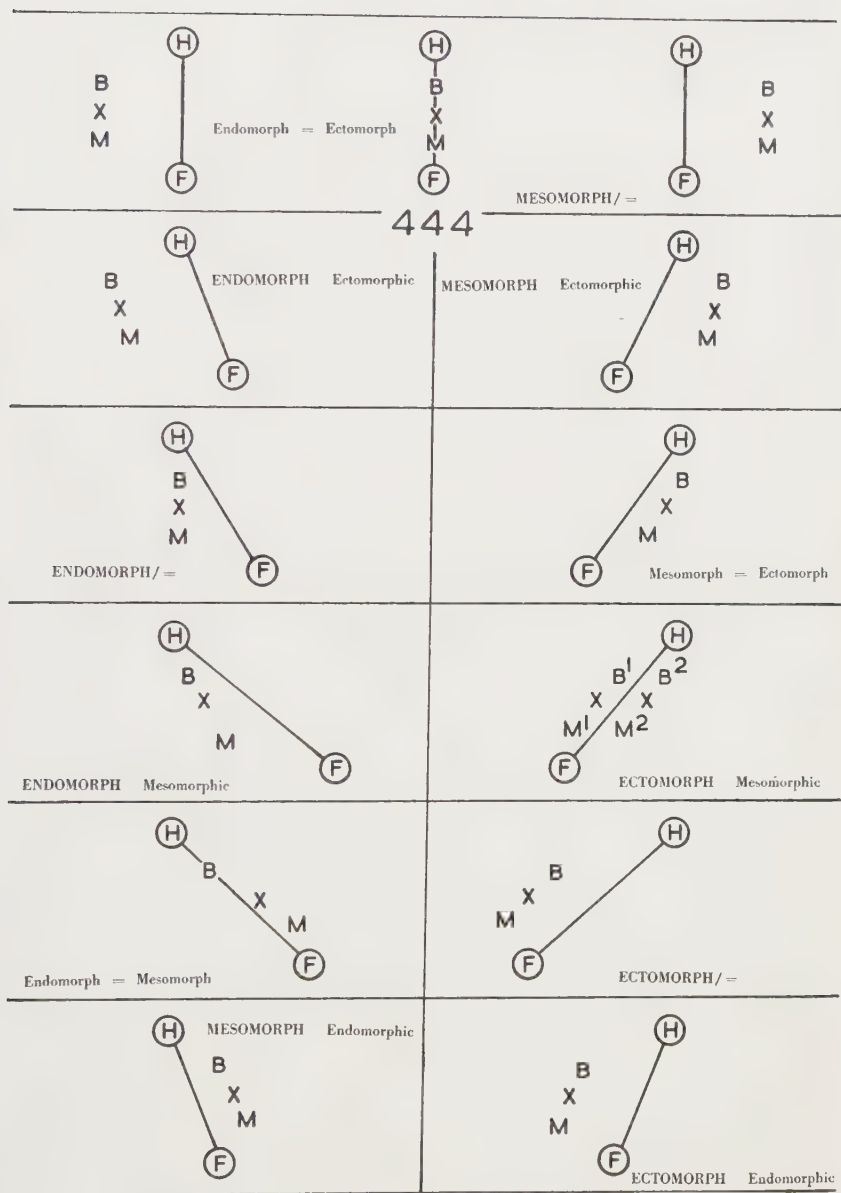


Fig. 2 Diagram illustrating the relationship of height (H), bone (B), muscle girth (M) and subcutaneous fat (F) standard scores on the deviation chart according to dominance of somatotype in a person of about average height.

Mesopenia (that is mesomorphy 3 or less) is present where the "BM" average point lies to the left of the "HF" line.

The layout of the standard deviation chart is such that the horizontal line on which the "BM" average is marked lies halfway between the height and total fat lines. When the "BM" cross falls on the "HF" line a rating of mesomorphy 4 is found. As a further rough guide, if the "BM" cross is discovered to the right of the "HF" line half a point in mesomorphy is gained for each column passed. Conversely, mesopenia may be roughly estimated by half point reductions of mesomorphy for each column lying between the midpoint of the "HF" line and the "BM" average point to its left. There is an exception. In endomorph-mesomorphs the primary dominance is shared but the girth measurements which here contain a fair proportion of fat give a slightly exaggerated impression of mesomorphy. Allowance has to be made for this, the actual amount depending on the total fat estimate. A reduction in mesomorphy by half a point is usual but reductions of one unit may be necessary in the presence of obesity.

One further explanatory note to the diagram concerns mesomorphic-ectomorphs. "B¹M¹" profiles relate to the mesomorphic-ectomorphs with low mesomorphy, somatotypes 235, 236, 136, 126 and 127. "B²M²" points lying to the right of the "HF" line relate to somatotypes 145, 245 and 345 where mesomorphy is rated higher.

So far these empirical instructions appear perhaps a little complicated. A momentary pause in which to consider the underlying reasons for this procedure may therefore be an advantage. The first point is that, in the process of Sheldonian somatotyping, size as expressed in terms of height is excluded; the main concentration of interest is on body shape, which is expressed in body proportions. Height is therefore taken as the starting point for the guide line "HF." It must further be remembered that endomorphy and mesomorphy are defined as mutually exclusive components. If "F" is accepted as the other reference point for the guide line, the

mesomorphy estimate based on the relationship of bone and muscle measurements to this guide line will be relatively great where "F" has a low value; conversely it will be relatively low where there is a large amount of fat and the guide line "HF" thereby moves to the right.

The last stage in estimating somatotype is to select the most suitable type with appropriate ponderal index and component dominance from Sheldon's set of tables. This stage may or may not be completed during clinical interview according to choice.

Further notes on profile interpretation

While it is understood that suitable ponderal index-somatotype tables for each 5-year age group from 18 to 63 will shortly be published, it must be remembered that the standard deviation chart is standardized for 18- to 24-year-old men. Although the bone measurements do not change, the deviation chart remains unsuitable for older persons unless appropriate allowance for age changes in muscle girth and subcutaneous fat can be made. Further reference is made to this in a later section.

Comparatively low bone standard scores have been noticed in endomorphs, but skinfold measurements have been used as the main guide to endomorphy. Fat measurements may clearly be affected to a considerable degree by environmental influence, and the same is true, though to a smaller extent, of the girth measurements used in estimating mesomorphy. It is likely therefore that the results only approximate the somatotype, where it is known that the subject is neither greatly overweight nor wasted. Endomorphy and mesomorphy have not themselves been measured, if indeed they ever can be precisely in terms of their original definition.

Mesomorphy was defined⁴ as "relative predominance of muscle, bone and connective tissue," that is of tissues derived from the mesoderm or embryonic layer. Evidence from the

⁴ "Varieties of Human Physique," p. 5.

deviation chart profiles shows that although bone and muscle follow fairly consistent patterns by dominance of somatotype, they nevertheless vary somewhat independently of one another.

It has already been mentioned that the last stage of the procedure just described for estimating somatotype involves a change from body proportions based on the "extensive" scales of the deviation chart to the 7-point "equal appearing interval" scales of somatotype components. Practically, the adjustment required in the middle part of the scales is small, seldom if ever exceeding a half point, and this is fortunate because central somatotypes often present difficulty photoscopically. Towards the ends of the scales it is sometimes less easy to interpret a profile correctly, and experience is necessary to read the right answer at sight, but extreme physiques are less difficult to recognize photoscopically.

A further difficulty arises from the point already mentioned that fat contributes to girth measurements. In ectomorphs there is less than average fat to contribute to muscle girth and consequently the smaller girth measurements may lead to underestimates of mesomorphy. But among endomorphs and many endomorphic-mesomorphs there is more than average fat, and mesomorphy is apt to be overestimated in consequence, a 443 for example being incorrectly interpreted as a 44½3. The effect of this was not fully appreciated when first attempts were made to sight-read the profiles and the result was to rotate the whole distribution slightly clockwise.

Objective estimate of dominance by tables

Partly to correct this rotation and further to make due allowance for the effect of height on other measurements, tables (see appendix) were prepared to indicate the balance of endomorphic-mesomorphic dominance for each height and ponderal index group separately. These tables were constructed in the following manner: first the average bone, girth and total fat measurements were calculated for each

height and ponderal index separately; scales were then built around the average measurements using the same half standard deviation units as on the deviation chart. Next the average endomorphy and mesomorphy ratings were calculated for each ponderal index group among Oxford men (see table 5). Finally the scales were placed against the appropriate top line estimates of endomorphy and mesomorphy, so that the mean measurements and the mean somatotype ratings came into the same column. Thus a guide to the balance of endomorphic-mesomorphic dominance was obtained by comparing total fat equivalent in endomorphy with the average

TABLE 5

Mean ratings in endomorphy and mesomorphy for each ponderal index in Oxford undergraduates aged 17-24

PONDERAL INDEX	AVERAGE RATING	
	Endomorphy	Mesomorphy
Less than 12.45	4.9	4.0
12.50-12.95	4.1	3.9
13.00-13.45	3.5	3.8
13.50-13.65	3.0	3.3
13.70-13.95	2.7	2.7
14.00 +	1.9	2.0

estimate of mesomorphy obtained from the 4 measurements, two of bone and two of muscle girth, which mainly contribute to this component.

Six examples are given below, one from each ponderal index group, to illustrate the use of the tables and a variety of somatotype dominance.

1. Height 73.6 ins. Weight 134 lbs. Ht./ $\sqrt[3]{\text{Wt.}}$ 14.4. Age 21

Endo-meso estimate

“B”	Humerus	6.7 cm	1.00	} 2.0	Most fitting somatotype from Sheldon’s tables with dominance suggested by 2.4/2.0 is:
	Femur	9.6 cm	1.75		
“M”	Biceps	27.7 cm	2.50		
	Calf	35.0 cm	2.90		
			4/ 8.15		
Total fat	32.0 mm		2.4	21½	

2. Height 73.25 ins. Weight 158 lbs. Ht./
- $\sqrt[3]{\text{Wt.}}$
- 13.55. Age 18.

Endo-meso estimate

“B”	Humerus	6.8 cm	2.25	} 2.7	Most fitting somatotype from Sheldon’s tables with dominance suggested by 4.0/2.7 is:
	Femur	9.8 cm	2.75		
“M”	Biceps	29.2 cm	3.00		
	Calf	34.8 cm	2.75		
4/10.75					

Total fat 44.0 mm 4.0 42½

3. Height 69.6 ins. Weight 146 lbs. Ht./
- $\sqrt[3]{\text{Wt.}}$
- 13.2. Age 24.

Endo-meso estimate

“B”	Humerus	6.5 cm	2.50	} 3.75	Most fitting somatotype from Sheldon’s tables with dominance suggested by 2.1/3.75 is:
	Femur	9.8 cm	4.25		
“M”	Biceps	30.5 cm	4.50		
	Calf	34.8 cm	3.75		
4/15.00					

Total fat 20.0 mm 2.1 24¼

4. Height 71.4 ins. Weight 164 lbs. Ht./
- $\sqrt[3]{\text{Wt.}}$
- 13.1. Age 20.

Endo-meso estimate

“B”	Humerus	7.1 cm	4.00	} 4.5	Most fitting somatotype from Sheldon’s tables with dominance suggested by 4.0/4.5 is:
	Femur	9.5 cm	3.00		
“M”	Biceps	34.3 cm	5.50		
	Calf	39.4 cm	5.50		
4/18.00					

Total fat 42.0 mm 4.0 443

Note: On account of the fat in the girth measurements, a reduction of the mesomorphic estimate is required if a close fit is to be found in Sheldon's tables.

5. Height 72.9 in. Weight 184 lbs. Ht./
- $\sqrt[3]{\text{Wt.}}$
- 12.8. Age 23.

Endo-meso estimate

“B”	Humerus	7.2 cm	4.25	} 4.5	Most fitting somatotype from Sheldon’s tables with dominance suggested by 2.6/4.5 is:
	Femur	10.5 cm	4.50		
“M”	Biceps	35.6 cm	5.10		
	Calf	39.4 cm	4.00		
			4/17.85		

Total fat 26.0 mm 2.6 2½2

6. Height 65.25 ins. Weight 147 lbs. Ht./
- $\sqrt[3]{\text{Wt.}}$
- 12.35. Age 18.

Endo-meso estimate

"B"	Humerus	6.6 cm	4.25	} 4.1	Most fitting somatotype from Sheldon's tables with dominance suggested by 5.4/4.1 is:
	Femur	9.1 cm	3.25		
"M"	Biceps	32.5 cm	5.35		
	Calf	35.1 cm	3.60		
4/16.45					

Total fat 60.0 mm 5.4 5½31½

Note: A reduction of one unit in the estimate of mesomorphy was required in order to find a close fit in Sheldon's tables, where the total fat (60 mm) was much above average.

Certain practical hints

The tables give an estimate of the direction of endomorphic-mesomorphic dominance, but in adjusting this estimate to somatotype ratings experience shows that:

(a) There is a tendency to underestimate mesomorphy among mesomorphs with low endomorphy (see examples 3 and 5) because there is less than average fat in the girth measurements, and furthermore where endomorphy exceeds ectomorphy in secondary dominance, endomorphic influence tends to lower bone standard scores also.

(b) Conversely in mesopenes, especially central or ectomorphic mesopenes, bone size standard scores are commonly larger than girth scores although the girth scores are to some degree swollen by fat content. In short there is a tendency to overestimate mesomorphy and to underestimate mesopenia. Additional evidence in mesopenes that the table estimate of mesomorphy needs lowering will be found in feminine features such as maximal fat appearing over the triceps, or a low androgyny score, or again if chest width and depth are both small in relation to height.

It is correct to stick closely to Sheldon's ponderal index tables in the final estimate, but it increases confidence to know in what direction the slight adjustments of provisional endomorphy-mesomorphy estimates are likely to be necessary according to areas on the somatotype chart. Lastly it is well to remember that in persons more than two inches shorter or taller than the inner limit of the end categories in the tables provided still further allowance may be necessary for the effects of height.

Dysplasia. With the above points in mind it should be possible to estimate the somatotype of a healthy young man who is neither over nor under average weight for his build. The most common difficulty encountered is that connected with the presence of dysplasia, whether this is between the primary components or in the form of gynandromorphy.

Hints of both may be present on the deviation chart, for example:

1. Humerus and biceps scores may be small and femur and calf scores high or vice versa indicating uneven development of arms and legs.

2. A low androgyny score and/or high skinfold score over triceps compared with elsewhere are common feminoid features in men.

In other forms of dysplasia between the limbs and trunk there may be no indication on the deviation chart and it happens every now and again (2 or 3% in the Oxford series) that the dominance of the head and neck, thorax and abdomen is the reverse of that in the limbs. It is in such cases that the photographic record is particularly valuable in preventing incorrect estimates, quite apart from the other information it may provide. If therefore, say on grounds of economy, no photograph is obtained, a special point should be made of looking for reversal of dominance during clinical inspection. Much valuable information will certainly be lost if use of the deviation chart and tables is allowed to replace clinical or photographic inspection. The question is in fact often asked as to whether somatotyping may be carried out using the measurements and tables alone, without even the deviation chart. Certainly an answer may be obtained in this way but the risk of error is greater; for the procedure although objective is blind, and if suitable allowance is to be made for dysplastic anomalies it is better to keep the profile in view just as it is better not to relinquish the photographic record.

Possible sources of criticism. The standard scales derived from measurement of university students are representative neither of the general population nor of other special populations, say in the armed forces or in industry, whom it may be desirable to somatotype. The peculiar advantage of this highly selected university group is that on the average the

Oxford students are taller and heavier than any other section of the community and this may be taken as the physical expression of a high tide mark in total endowment, both bodily and mental. According to Sheldon's scheme the total rating of his three components should add up to no more than 12 in the most highly endowed somatotypes; thus it is reasonable for somatotype 444 of average height to have in addition the average measurements of the group in whom physical expression of total endowment reaches its highest level. For somatotyping it is not supremely important that the deviation chart scales should represent any particular population in an absolute sense. Such scales would in any case be liable to revision to allow for secular trends in growth and nutrition. The main concern in somatotyping is with body shape, that is the sum of body proportions of which the profile is the outline. What scales are used is of less account, the more important point being that all investigators should use the same standards.

Apprehension is sometimes felt that mingling two methods so essentially different in their approach as photographic inspection and physical measurement may lead to confusion, but the deviation chart should be regarded as an aid in objectification, as a means of grading small differences the sum of which in widely contrasting physiques is obvious enough to the veriest beginner examining photographs.

The purist may claim that the deviation chart procedure is not somatotyping on the grounds for example that endomorphy cannot be defined solely in terms of subcutaneous fat. But skinfold measurements are a more accurate guide to subcutaneous fat than photographic estimates of this feature. Thus it may come about in practice that gains in exactness of measurement at any given time may outweigh loss of a partly speculative hope that the "morphogenotype" can be assessed more precisely by photographic inspection. But whatever view is taken it seems that the same or at least a closely allied objective is being pursued by both methods,

otherwise it is hard to understand why such close agreement should obtain between the results.⁵

What has been said relates to healthy persons. When somatotyping ill people it should help to inquire into the subject's weight history, weight at 18 years and subsequently if obtainable, the highest known weight and the subject's belief as to his optimum weight. The standard photograph is of special value to a skillful interpreter but looseness of the skin, from wasting or dehydration, is unlikely to be missed by the physician who carries and uses subcutaneous tissue calipers.

Use of the deviation chart for estimating the somatotype of older men. Without testing the method against a sufficiently large sample of older subjects who have been somatotyped when young no absolutely reliable conclusion can be reached, but there are several points about the deviation chart which suggest that its use might be developed for older age groups. First, height and bone width measurements were more or less constant from 21 to 29 years of age and it is probable that they change little up to the age of 50 and possibly afterwards. Analysis of calf girth measurements showed an insignificant increase with age from 17 to 30 years; in the same period there was an increase in biceps girth, significant in the statistical sense, but amounting to little more than half a standard deviation, that is one column on the deviation chart. In this increase fat is probably the chief factor and the chief age variables to be considered on the deviation chart are therefore the weight and skinfold measurements. Their variation may be gauged to some extent,

⁵ Hunt ('52) reviews a rather different system of classification being developed by Professor E. A. Hooton and his associates. In this the first component is simply called "fat," and the second "muscularity," the third component being derived from the ponderal index or "index of attenuation" as he calls it. The method is easier to operate than Sheldon's technique, but ratings obviously change to a great extent with variations in weight caused by age, diet, exercise or illness, whereas Sheldon contends, how rightly is uncertain but perhaps more rightly than many of his opponents admit, that his somatotype ratings are nearly independent of environmental influence.

especially if an older subject happens to know what his weight was at the age of 18. If not, the average weight variation with age is indicated by standard age, height and weight tables, though these make no allowance either for individual somatotype or for secular trends. If in such tables in place of weight for each height and age the appropriate ponderal index is given instead, it appears that whatever the individual's height a reduction of approximately 0.7 occurs in the ponderal index between the ages of 18 and 50; of this about 0.2 occurs in the first 4 years, 0.3 by 27, 0.4 by 32, 0.5 by 37 and the remainder in the last 15 years. The majority of persons are likely to require midrange or near average adjustments but it must be stressed that no exact allowance can be made in this way for weight changes characteristic of individual somatotype; for these Sheldon gives numerous descriptive notes in "Varieties of Human Physique."

The increasing trend in mean values of subcutaneous fat measurements associated with age in the present series was significant, but under the age of 30 amounted to less than half a unit on the standard scale for the total of three fat measurements. The mean value of course conceals what really matters here, namely what happens to individuals, but the standard deviation was also found to increase. Such a widening of the scatter might occur if say endomorph-mesomorphs mature early on one side of the mean while persons with low ratings in endomorphy reach their mature weight later, some after 30 years of age, others never gaining weight at all.

Use of the deviation charts for estimating the somatotype of women. No metric standards have been published for women so far, no index file or reference atlas of known somatotypes. There being no source of reference it is impossible to tell how far a provisional estimate of somatotype reached by applying certain guiding rules of interpretation to the deviation chart would in fact approximate to the Sheldonian somatotype. Doctor Sheldon has, however, been kind enough

to show me a distribution chart of 1,000 college women in the United States. The greatest concentration on this chart is immediately below somatotype 543 in the triangle 543, 533, 433. Now if the average measurements of Oxford women students are plotted on the male deviation chart and the guiding rules are used to arrive at a provisional estimate of the average woman's somatotype, it will be found to work out as 433½. This is virtually identical with the central concentration of American women students. Furthermore, Sheldon uses the same ponderal index scales for women as he does for men. It therefore seems very likely that the primary component scales of endomorphy, mesomorphy and ectomorphy approximate more closely to male standards, which would not be surprising since the earliest work was based on the study of 4,000 college men.

Standard scales for women. The question therefore arises as to how appropriate such scales are for women and anyone who takes the trouble to plot women's measurements on a man's deviation chart will soon find a number of women with measurements beyond the standard scales. It is for this reason that in the deviation chart illustrated the scales have been extended downward to cover the range of Oxford women's measurements, their mean values being indicated by boxes.

On the other hand investigators may feel that a deviation chart based on women's measurements is more appropriate for women; they may prefer dimensions whose nature is more exactly understood than that of the so-called primary components. If these components are primary in the biological sense that they originate in a common germ cell for men and women, it might be more logical to choose measurements halfway between the average man and the average woman as the definition of the central somatotype 444. But it is not so easy to change ships in mid-ocean. The ship of somatotyping was launched over 13 years ago. A great deal of work has already been done on the correlation of somatotype with traits of temperament, psychosis and psychoneuro-

sis. In addition if a change is to be recommended to women's standards the only ones at present available are based on the measurements of college women. Although this highly selected group has the one distinct advantage already mentioned, it must not be forgotten that it differs physically from the general population. For example the average ponderal index at Oxford was 12.86 and although this is very close to the figure for American college women, a ponderal index derived from the average height and average weight of 18-year-old insured women would be about 13.1.

From the quandary thus reached it is necessary to return to the primary question and purpose of this discussion — can a deviation chart be used to estimate the Sheldonian somatotype of women? The only reasonable answer at present is that by using a man's deviation chart it may be possible but it has not yet been shown how closely this may be done except in the case of the "average Oxford woman." If an investigator, on the other hand, prefers to type women against women's standard measurements, he may use their deviation chart and follow rules of interpretation of his own. In this case it would have to be clearly understood that if no reference is made to Sheldon's tables the results obtained would be quite distinct from and probably not even a close approximation to Sheldonian somatotype. The final choice of standards is likely to be settled by comparing the usefulness of each method for the particular purpose in view.

SUMMARY AND CONCLUSIONS

1. A method is described of estimating Sheldonian somatotype in young men, aged 17 to 24, by physical anthropometry. Since the measurements occupy only 5 minutes in the taking the method is suitable for general clinical use, the result being available in the form of a profile during the clinical interview. Greater objectivity in somatotyping is obtained by tables of bone, muscle girth and subcutaneous fat measurements for each height and ponderal index group. These tables provide a simple and reliable guide to dominance in

all but a small percentage of individuals who show reversal of dominance in trunk and limbs.

2. Agreement to half a unit was obtained in 90% of all somatotype ratings between estimates by deviation chart and tables and estimates made by the long photometric method. Between estimates by deviation chart and tables and photoscopic estimates by expert somatotypists agreement to half a unit was found in 87.3%.

3. The prospect for somatotyping by deviation chart and tables in older men and women subjects is discussed.

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APPENDIX

*Men aged 17-24*Height/ $\sqrt[3]{\text{weight}}$ < 12.50

HEIGHT INCHES	ENDO-MESO ESTIMATE	2	2½	3	3½	4	4½	5	5½	6	6½
< 64	Humerus, cm	5.6	5.8	5.9	6.1	6.3	6.5	6.6	6.8	7.0	
	Femur, cm	8.1	8.3	8.5	8.7	8.9	9.1	9.3	9.5	9.7	
	Biceps, cm	23.7	24.8	26.0	27.1	28.2	29.3	30.4	31.5	32.7	
	Calf, cm	30.5	31.5	32.5	33.5	34.5	35.6	36.6	37.6	38.6	
	Total fat, mm	17	20	25	30	36	43	51	62	75	90
64-65.9	Humerus, cm	5.8	6.0	6.2	6.4	6.5	6.7	6.9	7.0	7.2	
	Femur, cm	8.6	8.8	9.0	9.2	9.4	9.6	9.8	10.0	10.2	
	Biceps, cm	25.0	26.1	27.2	28.3	29.5	30.6	31.7	32.8	33.9	
	Calf, cm	31.7	32.7	33.8	34.8	35.8	36.8	37.9	38.9	39.9	
	Total fat, mm	18	21	25	31	37	44	53	63	76	92
66-67.9	Humerus, cm	5.9	6.1	6.3	6.5	6.7	6.8	7.0	7.2	7.3	
	Femur, cm	8.8	9.0	9.2	9.4	9.6	9.8	10.0	10.2	10.4	
	Biceps, cm	28.0	29.1	30.3	31.4	32.5	33.6	34.7	35.9	37.0	
	Calf, cm	32.3	33.3	34.3	35.3	36.3	37.3	38.4	39.4	40.4	
	Total fat, mm	18	22	27	32	38	46	55	66	79	96
68-69.9	Humerus, cm	6.1	6.3	6.4	6.6	6.8	7.0	7.1	7.3	7.5	
	Femur, cm	9.0	9.2	9.4	9.6	9.8	10.0	10.2	10.4	10.6	
	Biceps, cm	27.3	28.4	29.5	30.6	31.7 ¹	32.8	33.9	35.1	36.2	
	Calf, cm	34.3	35.3	36.3	37.3	38.3	39.4	40.4	41.4	42.4	
	Total fat, mm	19	23	27	33	39	47	56	67	81	97
70-71.9	Humerus, cm	6.3	6.5	6.7	6.8	7.0	7.2	7.4	7.5	7.7	
	Femur, cm	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	
	Biceps, cm	29.6	30.7	31.8	32.9	34.0	35.1	36.2	37.4	38.5	
	Calf, cm	35.6	36.6	37.6	38.6	39.6	40.6	41.7	42.7	43.7	
	Total fat, mm	19	23	27	33	39	47	56	67	81	97
72 +	Humerus, cm	6.6	6.7	6.9	7.1	7.2	7.4	7.6	7.8	7.9	
	Femur, cm	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1	
	Biceps, cm	30.1	31.2	32.3	33.4	34.5	35.6	36.7	37.9	39.0	
	Calf, cm	35.3	36.3	37.3	38.3	39.4	40.4	41.4	42.4	43.4	
	Total fat, mm	19	23	27	33	39	47	56	67	81	97

¹ Although the calf measurement increases from height group 66-67.9 ins. to 68-69.9 ins. the biceps average decreases. This has been checked and is related it seems to there being more mesomorphs in the shorter group.

*Men aged 17-24*Height/ $\sqrt{\text{weight}}$ 12.50-12.95 inclusive

HEIGHT INCHES	ENDO-MESO ESTIMATE	2	2½	3	3½	4	4½	5	5½	6
< 66	Humerus, cm	6.0	6.2	6.3	6.5	6.7	6.8	7.0	7.2	7.4
	Femur, cm	8.6	8.8	9.0	9.2	9.4	9.6	9.8	10.0	10.2
	Biceps, cm	24.5	25.6	26.7	27.8	29.0	30.1	31.2	32.3	33.4
	Calf, cm	31.0	32.0	33.0	34.0	35.1	36.1	37.1	38.1	39.1
	Total fat, mm	18	21	26	31	37	44	53	64	77
66-67.9	Humerus, cm	6.1	6.3	6.5	6.7	6.8	7.0	7.1	7.3	7.5
	Femur, cm	8.7	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3
	Biceps, cm	25.8	26.9	28.0	29.1	30.2	31.3	32.4	33.6	34.7
	Calf, cm	31.2	32.3	33.3	34.3	35.3	36.3	37.3	38.4	39.4
	Total fat, mm	19	22	26	31	37	44	53	64	77
68-69.9	Humerus, cm	6.3	6.5	6.7	6.8	7.0	7.2	7.3	7.5	7.7
	Femur, cm	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.5
	Biceps, cm	26.5	27.6	28.7	29.9	31.0	32.1	33.2	34.4	35.5
	Calf, cm	32.3	33.3	34.3	35.3	36.3	37.3	38.4	39.4	40.4
	Total fat, mm	19	23	28	33	40	48	58	69	83
70-71.9	Humerus, cm	6.4	6.6	6.8	6.9	7.1	7.3	7.5	7.6	7.8
	Femur, cm	9.2	9.4	9.6	9.8	10.0	10.2	10.4	10.6	10.8
	Biceps, cm	27.8	28.9	30.0	31.1	32.3	33.4	34.5	35.6	36.7
	Calf, cm	33.5	34.5	35.5	36.6	37.6	38.6	39.6	40.7	41.7
	Total fat, mm	20	24	29	35	42	50	60	72	87
72 +	Humerus, cm	6.4	6.6	6.8	6.9	7.1	7.3	7.5	7.6	7.8
	Femur, cm	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1
	Biceps, cm	28.5	29.7	30.8	31.9	33.0	34.1	35.2	36.4	37.5
	Calf, cm	35.3	36.3	37.3	38.3	39.4	40.4	41.4	42.4	43.4
	Total fat, mm	21	25	30	36	43	52	62	75	90

*Men aged 17-24*Height/ $\sqrt[3]{\text{weight}}$ 13.00-13.45 inclusive

HEIGHT INCHES	ENDO-MESO ESTIMATE	2	2½	3	3½	4	4½	5	5½	6
< 66	Humerus, cm	6.1	6.3	6.4	6.6	6.8	6.9	7.1	7.3	7.4
	Femur, cm	8.5	8.7	8.9	9.1	9.3	9.5	9.7	9.9	10.1
	Biceps, cm	23.5	24.6	25.7	26.8	27.9	29.1	30.2	31.3	32.4
	Calf, cm	29.5	30.5	31.5	32.5	33.5	34.5	35.6	36.6	37.6
	Total fat, mm	17	21	25	30	36	43	52	62	75
66-67.9	Humerus, cm	6.2	6.3	6.5	6.7	6.9	7.0	7.2	7.4	7.5
	Femur, cm	8.7	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3
	Biceps, cm	24.5	25.6	26.7	27.8	29.0	30.1	31.2	32.3	33.4
	Calf, cm	30.7	31.7	32.8	33.8	34.8	35.8	36.8	37.9	38.9
	Total fat, mm	18	22	26	32	38	46	55	66	79
68-69.9	Humerus, cm	6.4	6.5	6.7	6.9	7.0	7.2	7.4	7.5	7.7
	Femur, cm	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.5
	Biceps, cm	25.0	26.1	27.2	28.3	29.5	30.6	31.7	32.8	33.9
	Calf, cm	31.2	32.3	33.3	34.3	35.3	36.3	37.3	38.4	39.4
	Total fat, mm	19	23	28	33	40	48	58	69	83
70-71.9	Humerus, cm	6.4	6.6	6.7	6.9	7.1	7.3	7.4	7.6	7.8
	Femur, cm	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7
	Biceps, cm	26.3	27.4	28.5	29.6	30.7	31.9	33.0	34.1	35.2
	Calf, cm	32.2	33.3	34.3	35.3	36.3	37.3	38.4	39.4	40.4
	Total fat, mm	19	23	28	34	41	49	59	71	85
72-73.9	Humerus, cm	6.6	6.8	6.9	7.1	7.3	7.5	7.6	7.8	8.0
	Femur, cm	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9
	Biceps, cm	27.0	28.1	29.3	30.4	31.5	32.6	33.7	34.9	36.0
	Calf, cm	33.0	34.0	35.0	36.1	37.1	38.1	39.1	40.1	41.2
	Total fat, mm	20	24	29	35	42	50	60	72	87
74 +	Humerus, cm	6.8	7.0	7.2	7.3	7.5	7.7	7.9	8.0	8.2
	Femur, cm	9.4	9.6	9.8	10.0	10.2	10.4	10.6	10.8	11.0
	Biceps, cm	28.5	29.7	30.8	31.9	33.0	34.1	35.3	36.4	37.5
	Calf, cm	33.8	34.8	35.8	36.8	37.9	38.9	39.9	40.9	41.9
	Total fat, mm	20	24	28	34	41	49	59	71	85

*Men aged 17-24*Height/ $\sqrt[3]{\text{weight}}$ 13.50-13.95 inclusive

HEIGHT INCHES	ENDO-MESO ESTIMATE ¹	1	1½	2	2½	3	3½	4	4½	5
< 68	Humerus, cm	5.9	6.1	6.2	6.4	6.6	6.7	6.9	7.1	7.2
	Femur, cm	8.2	8.4	8.6	8.8	9.0	9.2	9.4	9.6	9.8
	Biceps, cm	22.0	23.1	24.2	25.3	26.4	27.5	28.7	29.8	30.9
	Calf, cm	27.9	28.9	30.0	31.0	32.0	33.0	34.0	35.1	36.1
	Total fat, mm	13	16	19	23	28	34	40	49	58
68-69.9	Humerus, cm	6.2	6.3	6.5	6.7	6.9	7.0	7.2	7.3	7.5
	Femur, cm	8.6	8.8	9.0	9.2	9.4	9.6	9.8	10.0	10.2
	Biceps, cm	23.2	24.3	25.4	26.6	27.7	28.8	29.9	31.1	32.2
	Calf, cm	29.5	30.5	31.5	32.5	33.5	34.5	35.6	36.6	37.6
	Total fat, mm	14	17	20	24	29	35	42	50	60
70-71.9	Humerus, cm	6.3	6.5	6.6	6.8	7.0	7.1	7.3	7.5	7.6
	Femur, cm	8.8	9.0	9.2	9.4	9.6	9.8	10.0	10.2	10.4
	Biceps, cm	23.2	24.3	25.4	26.6	27.7	28.8	29.9	31.1	32.2
	Calf, cm	30.0	31.0	32.0	33.0	34.0	35.1	36.1	37.1	38.1
	Total fat, mm	14	17	20	24	29	35	42	50	60
72-73.9	Humerus, cm	6.4	6.5	6.7	6.9	7.0	7.2	7.4	7.5	7.7
	Femur, cm	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7
	Biceps, cm	24.7	25.9	27.0	28.1	29.2	30.3	31.4	32.6	33.7
	Calf, cm	31.2	32.3	33.3	34.3	35.3	36.3	37.3	38.4	39.4
	Total fat, mm	15	18	21	26	31	37	45	52	64
74 +	Humerus, cm	6.5	6.7	6.9	7.0	7.2	7.4	7.5	7.7	7.9
	Femur, cm	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9
	Biceps, cm	25.3	26.4	27.5	28.6	29.7	30.8	32.0	33.1	34.2
	Calf, cm	31.7	32.7	33.8	34.8	35.8	36.8	37.9	38.9	39.9
	Total fat, mm	15	18	22	27	32	38	46	55	67

¹ When height/ $\sqrt[3]{\text{weight}}$ is 13.80, 13.85, 13.90 or 13.95, reduce each estimate by half a unit. This reduction is a consequence of increasingly dominant ectomorphy and the exclusive effect of this on the other two Sheldonian components.

*Men aged 17-24*Height/ $\sqrt[3]{\text{weight}}$ 14.00 +

HEIGHT INCHES	ENDO-MESO ESTIMATE	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$
< 70	Humerus, cm	6.2	6.3	6.5	6.7	6.8	7.0	7.2
	Femur, cm	8.7	8.9	9.1	9.3	9.5	9.7	9.9
	Biceps, cm	22.6	23.7	24.8	25.9	27.0	28.1	29.3
	Calf, cm	28.4	29.5	30.5	31.5	32.5	33.5	34.6
	Total fat, mm	16	19	23	28	34	40	49
70-71.9	Humerus, cm	6.3	6.5	6.7	6.8	7.0	7.1	7.3
	Femur, cm	8.9	9.1	9.3	9.5	9.7	9.9	10.1
	Biceps, cm	22.6	23.7	24.8	25.9	27.0	28.1	29.3
	Calf, cm	29.5	30.5	31.5	32.5	33.5	34.5	35.6
	Total fat, mm	16	19	23	28	34	40	49
72 +	Humerus, cm	6.5	6.7	6.8	7.0	7.2	7.3	7.5
	Femur, cm	9.1	9.3	9.5	9.7	9.9	10.1	10.3
	Biceps, cm	23.1	24.2	25.3	26.4	27.5	28.7	29.8
	Calf, cm	30.2	31.2	32.3	33.3	34.3	35.3	36.3
	Total fat, mm	16	19	23	28	34	40	49



MORFOLOGIA INFANTIL (CRECIMIENTO). Juan Comas. (Reprinted from *Paidologia* by Jose Peinado Altable, Chapter VI, pp. 221-349. 136 pp., 17 graphs and figures, 89 tables. Mexico, 1952.) — A summary account of child growth which includes tabular material from the world literature on the subject. Of special interest is the coverage of the Latin American data and literature.

BASIC BODY MEASUREMENTS OF SCHOOL AGE CHILDREN. By W. Edgar Martin. U. S. Department of Health, Education, and Welfare, Washington. 74 pp. 1953.— This free booklet published by the U. S. Department of Health, Education, and Welfare is straight applied physical anthropology and provides normative data on a variety of body measurements under the assumption that they will assist in the proper manufacture of school equipment. Although some anthropologists may object to weighted means and common standard deviations obtained by combining diverse series measured over a 20-year range, it is not likely that today's data would be too very different. And while the definition of nasion as "a point between the eyes" may be inadequate for routine anthropometry, the imprecision should not affect manufacturers of blackboards, windows, or child-size wash-basins. Fortunately, all measurements are reported in inches and tenths of an inch.

Mr. Martin carefully distinguishes between the static measurements customarily taken and the dynamic measurements that usually cannot be extrapolated from them. While it is important for manufacturers to realize these limitations of conventional body measurements, it is even more important for them to realize that the arithmetic mean is usually the poorest possible statistic to use when human comfort is concerned. What is not included in this booklet, namely the theory of applied physical anthropology, is missing because it has not been written by applied physical anthropologists themselves. — S. M. GARN.

MAN IN EVOLUTION. M. R. Sahni. (272 pp., $5\frac{1}{2} \times 9$, illustrated by Kamini Sahni. 15 shillings. Longmans Green and Co., London. 1953.) — This account of human evolution by an Indian author is intended mainly for Indian readers, and includes a survey of what is known of the prehistory of India and the neighboring countries. — G. W. LASKER.

GENE FREQUENCIES IN ANTHROPOLOGY: SIMPLE METHODS

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The use of blood group data in physical anthropology is still increasing, as shown by numerous papers in this journal, and articles and books published elsewhere (Mourant, '54a; Boyd, '54b; Mourant, '54b). It seems clear that the physical anthropologist of the future will find genetic methods in general an important part of his operational technique.

For blood group determinations to be of value to the anthropologist, they must be carried out on a suitable sample of the population, and by reliable techniques. The choice of the sample is governed by the same considerations as in other types of physical anthropological work, and involves no new principles. The actual technique of blood grouping is adequately described in various manuals (Schiff and Boyd, '42; Wiener, '43; Race and Sanger, '50), and in addition commercial grouping sera are usually accompanied by printed directions as to their proper use. In general these two problems have been considered by the workers concerned and dealt with insofar as the situations permitted.

Before such data are utilized as physical anthropological criteria, another process is desirable. This is the estimation of the frequencies of the genes responsible, in the population, for the particular phenotypes observed, and this third process has not always been most efficiently carried out. A comparison of gene frequencies is more directly informative than a comparison of crude percentages of phenotypes. It is common knowledge that the gene frequencies cannot generally be accurately estimated by mere inspection of the data. For in-

stance, the observation of 36% group A in a population containing 64% of group O means just half as much gene A as does 36% group A in a population containing only 6.25% group O. The reason, of course, is that in the former population many more of the individuals of group A are heterozygotes of genetic formula AO. We obviously want to be able to take such factors into consideration in making comparisons.

Gene frequencies have many other advantages over crude phenotypic frequencies. For example, they must be used in calculating the phenotypic frequencies to be expected from mixtures of races or stocks having different frequencies of one or more genetically determined characters. And from gene frequencies calculations as to the degree of race mixture which a given hybrid group represents may be made (Da Silva, '48; Boyd, '49, '50).

Finally, gene frequencies are more compact to tabulate and study than are crude phenotypic frequencies. The frequencies of the 4 classical blood groups in populations reduce to the frequencies of three genes, the sum of which is unity; effectively, two of these parameters serve to characterize a population. The 6 MNS classes (9 if an anti-s serum is used) can be expressed in terms of the frequencies of 4 genes. The various combinations of frequencies of 27 Rh phenotypes in populations can be summarized in terms of the frequencies of just 8 genes.

The gene frequencies are not something which we can observe directly or get by intuition. In any actual case, the only information we have as to the gene frequencies of our sample (and hence the parent population) is that provided by the data. Consequently we want to make the best use of that information which modern statistical methods permit. This has not always been done (e.g. Da Silva, '48). Nevertheless, to do so is usually not difficult.

If all the genotypes can be distinguished by direct test, the computation of gene frequencies is simple and straightforward, and presents no difficulties. An example of such a situation is furnished by the MN blood groups, where there are three

genotypes and three phenotypes, and the gene frequencies are found by direct counting (Wiener and Vaisberg, '31) to be

$$m = M + MN/2$$

$$n = N + MN/2$$

where m and n are the frequencies of the genes M and N , and M , MN and N are the frequencies (per cent divided by 100) of the respective groups in the sample.

If a population is in genetic equilibrium, it is easy to show that, in terms of the gene frequencies,

$$M = m^2$$

$$MN = 2mn$$

$$N = n^2$$

This means that the gene frequencies can be *estimated* from the relations

$$m = \sqrt{M}$$

$$n = \sqrt{N}$$

These relations were in fact used by some of the early workers, including the present writer (Boyd, '39). However, if the population is not in complete genetic equilibrium, they may give results which differ considerably from the accurate gene counting values, and in general constitute a poor estimate of the gene frequencies. For instance, in the case of a series of 886 MN tests reported by Christiansen (see Boyd, '39), the square root method gives for n the value of 0.41973, which differs by 0.02446, or 5.8%, from the correct value 0.44419.

It is easy to show that the square root method is intrinsically inferior to the gene counting method for the MN system, even though the results of the two methods may sometimes coincide. This depends upon the fact that the variance of the square root method is always greater. (The square root of the variance is the standard deviation.) The variance of the square root method (Bernstein, '30b; Mather, '51) is $(1 - n^2)/4G$, where n is the gene frequency and G is the number of persons examined, and the variance of the gene counting estimate is $n(1 - n)/2G$ (Stevens, '38). From the data of Christiansen we find the variance of $n = \sqrt{N}$ to be 0.0002265, and that of $n = N + MN/2$ to be 0.0001393. The smaller the variance, of course, the more precise our estimate.

Fisher ('50) has shown that the efficiency of any estimate can be found by computing the ratio

$$E = \frac{\text{Variance of most efficient estimate}}{\text{Variance of estimate in question}}$$

In the present case the gene count estimate is the most efficient possible (Wiener, '35; Stevens, '38), so we have, for the efficiency of the square root method

$$E = 0.0001393/0.0002265 = 61.5\%.$$

This is too low an efficiency to be desirable. In the present case it means throwing away $0.385 \times 886 = 341$ of the observations. To obtain by the square root method an estimate of n which would be known as precisely (have the same variance) as that obtained from the present data by the gene counting method would require the examination of 1440 subjects. Few workers, it may be surmised, value their time in the field so lightly that they would rather test an extra 554 persons than later estimate the gene frequencies by the proper method.

In the case of MN data the above argument may seem a little forced, for the gene counting method can always be applied to such data, and no reason exists for not doing so. But as soon as we encounter cases in which not all the genotypes are directly recognizable (e.g. some of the genes are dominant over others), the issue ceases to be academic. The best known example is the ABO blood groups. Here we have the genetic formulas

$$\begin{aligned} O &= r^2 \\ A &= p^2 + 2pr \\ B &= q^2 + 2qr \\ AB &= 2pq \end{aligned}$$

It is not possible, by routine laboratory test, to distinguish an individual of genotype AA from one of type AO, so a direct gene count is not possible. From the above formulas we may derive equations for the estimation of the gene frequencies. There are two possible sets:

Bernstein ('25)

$$\begin{aligned} r &= \sqrt{O} \\ p &= 1 - \sqrt{O} + B \\ q &= 1 - \sqrt{O} + A \end{aligned}$$

Wiener ('29)

$$\begin{aligned} r &= \sqrt{O} \\ p &= \sqrt{O} + A - \sqrt{O} \\ q &= \sqrt{O} + B - \sqrt{O} \end{aligned}$$

For populations in genetic equilibrium, the estimates obtained by either of these methods should add up to 1 exactly. For actual populations the sum generally falls short of, or exceeds, 1, and the results of the two methods do not agree. Nor is it sufficient (Boyd, '49) to take an average of the results of the two methods, although this has been proposed (Wellisch, '32), since both make use of the inefficient square root estimate of r , and the variances of p and q , as estimated by these methods (Bernstein, '30b), are larger than those of the best estimates (Stevens, '38). Clearly, if the better estimates are not too difficult to calculate, we ought to use them.

The estimation of gene frequencies from blood group data is only one of a general class of problems, in which we are faced with the task of estimating some parameter or parameters which characterize the population from which the sample was drawn. Fisher ('50) calls such estimated parameters "statistics," and points out that there usually exist both good and bad ways of estimating them. In the first place, we want an estimate which, if the sample were indefinitely increased, would tend to the true value of the parameter and not to some other value. Statistics which tend to the wrong value are called by Fisher inconsistent statistics. In the second place, of the consistent statistics, we of course prefer those subject to the least error, or in other words with the smallest variance. The estimates of a parameter, the error distribution of which tends to the normal distribution with the least possible variance, are called by Fisher efficient statistics, and he has shown that such efficient statistics can be found in all cases by his method of maximum likelihood.

We might say that the method of maximum likelihood consists in ascribing to the parent population from which our sample was drawn just those values of the parameters which would make greatest the likelihood of our getting the sample which we have in fact obtained. It is apparent from this that although some other method might be easier in a given case, or might even give as good a result, it hardly seems conceivable that it could give *superior* results.

The maximum likelihood method makes use of all the information about the parameter contained in each portion of the data, and, having the smallest possible variance, has maximum efficiency.

The principles of the maximum likelihood calculations are simple. One starts by writing the likelihood expression

$$L = C_1 \log E_1 + C_2 \log E_2 + \dots$$

where C_1 , C_2 , etc. are the numbers of individuals observed to fall into the various classes, and E_1 , E_2 , etc. are the expected numbers in these classes, expressed in terms of the parameter we wish to estimate. By differentiating this expression for the parameter, and setting the derivative equal to zero, the value of the parameter which makes L a maximum can in theory always be found. If one parameter only is involved, the calculations are usually quite simple (Mather, '51).

If several parameters are required, the calculations may be somewhat more complicated, but for the simple ABO blood group case they are far from difficult, as shown by Mather ('51). It has also been shown that they are relatively simple for MNS data (Boyd, '53).

In the case of ABO data, the maximum likelihood values for the gene frequencies can be obtained very simply, without going through such calculations, for Bernstein ('30a) showed that the general likelihood equations for this system could be solved by making simple adjustments to the frequencies as calculated by the approximate formulas. Let

$$D = 1 - (p + q + r)$$

where p , q , and r are obtained by the Bernstein formulas (above). Then Bernstein showed that the maximum likelihood equations were solved by new values

$$p' = p(1 + D/2)$$

$$q' = q(1 + D/2)$$

$$r' = (r + D/2)(1 + D/2).$$

The sum of these new values differs from unity by $D^2/4$, but they are nevertheless fully efficient (Stevens, '38), and no further correction is necessary. These adjustments are now generally used. Their only real disadvantage is that the process of obtaining them does not yield also estimates of the

standard deviations, as does the method of maximum likelihood.

It does not seem to have been pointed out that the gene frequencies obtained by the Wiener formulas (above) can also be adjusted, in an equally simple manner, to obtain efficient estimates. This is done by writing

$$\begin{aligned}p' &= (p + D) (1 - D/2) \\q' &= (q + D) (1 - D/2) \\r' &= (r + D/2) (1 - D/2)\end{aligned}$$

where $D = 1 - (p + q + r)$, and the values of p , q , and r are those obtained by the Wiener formulas. Use of these adjustments enables efficient estimates to be obtained from the gene frequencies given in the present author's compilation (Boyd, '39), which is still often referred to.

From data which include the results of determining the subgroups of A and AB, it is possible to estimate the gene frequencies p_1 , p_2 , q , and r by the method of maximum likelihood (Stevens, '38), but no adjustments analogous to the Bernstein adjustments or the adjustments just given are known, and indeed it is not likely that any could be found.¹ The addition of the distinction between the subgroups of course increases the usefulness of the ABO system.

The usefulness of the different blood group systems in distinguishing individuals and populations has been computed by

¹ However, if the gene frequencies are calculated by the usual formulas (Wellisch and Thomsen, '30):

$$\begin{aligned}r &= \sqrt{O} \\p_2 &= \sqrt{A_2 + O} - \sqrt{O} \\p_1 &= \sqrt{A_1 + A_2 + O} - \sqrt{A_2 + O} \\q &= \sqrt{B + O} - \sqrt{O}\end{aligned}$$

and we let $D = 1 - (p_1 + p_2 + q + r)$, we may write

$$\begin{aligned}r' &= (r + D/2) (1 - D/2) \\(p'_1 + p'_2) &= (p_1 + p_2 + D) (1 - D/2) \\q' &= (q + D) (1 - D/2)\end{aligned}$$

The values of r' and q' so obtained are efficient estimates for data where A_1 and A_2 are combined, though not exactly for data in which A_1 and A_2 are distinguished: the difference is seldom great. Estimates of p_1 and p_2 which do not differ greatly from the maximum likelihood estimates may now be obtained by writing

$$\begin{aligned}p''_1 &= p_1 / (p_1 + p_2) \times (p'_1 + p'_2) \\p''_2 &= p_2 / (p_1 + p_2) \times (p'_1 + p'_2)\end{aligned}$$

The values of p_1 , p_2 , q and r given as method (a) in the following paper (Boyd and Boyd, '54) have been calculated by this method.

Race and Sanger ('50) by summing the squares of the phenotype frequencies. The figures obtained represent the percentage of failures to distinguish two random samples of (English) bloods, and the larger the values given, the less useful the system. The figures are:

GENE SYSTEM	PER-CENT FAILURES
Rh	19.5
MNS	20.0
A ₁ A ₂ BO	32.8
MN (without S)	37.4
Duffy	53.8
P	61.5
Lewis	64.8
Kell	81.7
Lutheran	85.4

It will be seen that in spite of the distinction between A₁ and A₂ the ABO system is now in third place, and the first and second places are occupied by the Rh and MNS systems.

It is easy to show that the gene counting method of estimating the frequencies of the genes M and N is a maximum likelihood method (Stevens, '38; Wiener, '43), and thus of maximum efficiency.

The addition of an anti-S serum to the MN tests increases the number of phenotypes to 6 and increases the usefulness of the system as shown above, but it results in a system where the frequencies of the 4 genes (or chromosomes) Ms, MS, Ns, and NS cannot be determined by direct counting. It has been shown (Boyd, '53, '54a) that maximum likelihood estimates may be obtained rather simply from such data, and also from data obtained by tests in which an anti-s serum is also used.

If two phenotypes A and a are determined by the action of two genes, A and a, and A is dominant over a, or (which amounts to the same thing) we have available only one reagent, say anti-A serum, which detects the effects of one of the genes, then the only method of estimating the gene frequencies is the square root method, namely $p = \sqrt{(a)}$, $q = 1 - p = 1 - \sqrt{(a)}$. It is easy to show that this is also the maximum likelihood estimate in such a situation. This method is therefore used for

such characteristics as are determined by a pair of genes, one dominant. The discovery of the antithetical serum, anti-A, would at once convert the situation to one exactly like the MN system.

The estimation of gene frequencies for the Rh system is more complicated, because of the large number of genes and genotypes. It has been discussed by Fisher ('46, '47), who has proposed a general "method of free parameters" for carrying out the maximum likelihood calculations for such systems. His method involves the construction of matrices of the order 7×7 , and requires the inversion of 6×6 matrices, and has generally been considered difficult (Race and Sanger, '50). It has been shown that somewhat simpler computational methods, also making use of the method of maximum likelihood, will give the same estimates (Boyd, '54c).

In the meantime, methods of adjusting the crude estimates of gene frequencies obtained by use of the older formulas for the MNS and Rh systems, which, although not exact maximum likelihood estimates, are in general quite good, have been developed by Mourant ('54b). These methods will be compared with the fully efficient maximum likelihood methods for several sets of actual data in a subsequent paper (Boyd and Boyd, '54). The results show that Mourant's methods are quite good, in fact probably good enough for most purposes. They are definitely easier to calculate than the maximum likelihood estimates. Whether these approximate methods or the maximum likelihood methods are used in a given case might well depend upon the computational facilities available in any particular laboratory.

SUMMARY

Some of the problems involved in the anthropological use of blood group data are discussed, and the need for precise estimates of the relevant gene frequencies pointed out. New methods of adjusting crude gene frequency estimates for ABO and A_1A_2BO data are given. The method of maximum likelihood is outlined, and its unique value discussed. Attention is called to the new approximate methods of Mourant for MNS and Rh data.

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FIRST ISSUE OF "HUMAN BIOLOGY" UNDER NEW PUBLISHER APPEARS. — The first issue of *Human Biology* to be published by the Wayne University Press has recently appeared. The journal, founded by Raymond Pearl in 1929 and formerly published by The Johns Hopkins Press, has been taken over by the Wayne University Press. It is edited by Gabriel Lasker, assistant professor of anatomy, Wayne University College of Medicine. Associated with him are Dr. Josef Brožek (University of Minnesota), Dr. Donald Mainland (New York University School of Medicine), Dr. James N. Spuhler (University of Michigan), and Dr. Bentley Glass and Dr. William L. Straus, Jr. (both of The Johns Hopkins University). Doctor Brožek will edit a book review section, a new feature.

The journal is published in English but its pages are open to authors of all nations. Three papers from abroad appear in this issue. They deal with age of onset of the menses in Swedish women of differing body structure (Lennart Jacobson, University of Lund), the ratio of males to females among infants who die within their first year in Japan (Eiji Takahashi, Hirosaki University), and feeding in Bantu babies of South Africa (Eva J. Salber and Evelyn Bradshaw, Cape Town). The American contributors deal with growth patterns of the skull, differential infant mortality, and cultural factors affecting the study of human biology.

The September issue will contain a symposium edited by Dr. James Gavan of the Department of Anatomy of the Medical College of South Carolina on non-human primates and human evolution. The symposium was presented at the annual meeting of the American Association for the Advancement of Science at Boston last December. It will include a contribution by the late Earnest Albert Hooton,

for 40 years professor of physical anthropology at Harvard, and the issue is to be a memorial to him.

Science is developing in the direction of ever increasing specialization. However, *Human Biology* is dedicated to synthesizing efforts designed to bring into reality the dream of a larger Bioanthropology, The Science of Man. The new publishers state that the journal should contribute to the comprehensive study of man and his heredity, growth and aging, his response to physical environment, including nutrition and disease. The emphasis is on normal man, his individual and group similarities and differences. The journal will also welcome contributions on man's morphology and body composition, his biochemical characteristics and physiological functions, and his behavior. Manuscripts of articles and brief communications should be sent to the editor, Dr. Gabriel Lasker, 1401 Rivard Street, Detroit 7, Michigan.

The annual subscription rate will continue to be five dollars. Despite rising costs, the price has never increased. Subscriptions may be placed with the Wayne University Press, 4841 Cass Avenue, Detroit 1, Michigan.

RELATIVE DATING OF PITHECANTHROPUS.—Judging by the fluorine content, the skull and the femora of *Pithecanthropus*, and the animal bones from Trinil can be dated in the Middle Pleistocene; there is a very good concordance between the fluorine content of the human remains and that of the animals of the same deposit. The Wadjak skull II might, according to the fluorine test, be from the Upper Pleistocene. . . .

Very important with regard to the controversy on the contemporaneousness of the *Pithecanthropus* skull and the femur, is the fact that the fluorine content of both pieces is of the same order. This does not give conclusive evidence that both fragments belong to the same individual, nor even to individuals of a single species, but it is a conclusive argument for settling the dispute about the relative age of those bones, as it is evidence for a similar degree of antiquity of both pieces. Finally the contemporaneousness of the animal and of the human remains now has been established.—R. A. M. BERGMAN AND P. KARSTEN. The fluorine content of *Pithecanthropus* and of other specimens from the Trinil fauna. Proc. Koninkl. Nederl. Akad. Wetensch., ser. B, vol. 55, no. 2, 1952, pp. 150–152.



VIKING FUND MEDALIST FOR 1953

The American Association of Physical Anthropologists, on the unanimous recommendation of its Awards Committee, has selected Dr. Thomas Dale Stewart of the United States National Museum to receive the Viking Fund Medal and Award in Physical Anthropology for 1953.



THOMAS DALE STEWART

Doctor Stewart was born in Delta, a small town in Pennsylvania. After graduating from high school there he was invited by the president of the local bank to accept the job of messenger or runner. The bookkeeper resigned almost immediately and Dale was promoted to his job, with the additional responsibility of installing a mechanical bookkeeping system. Just when it appeared that Dale was destined for a career in banking, an old friend, John L. Baer, appeared on the scene. I think that we all are in debt to Mr. Baer, for it was he who saved Stewart for physical anthropology. Baer was an amateur naturalist and archeologist, and he was engaged in part-time work at the U. S. National Museum while doing graduate work at the George Washington University. He succeeded in persuading Stewart to renounce the flesh-pots of high finance and to go to Washington with him to enter George Washington.

In 1924, when Baer went to Panama with the Marsh Expedition to study the "White Indians," he arranged for Stewart to act as his substitute at the National Museum with the title of Temporary Aide in Physical Anthropology under Dr. Aleš Hrdlička. Baer's untimely death in Panama gave Stewart the opportunity to continue work with Hrdlička and so to receive practical training in physical anthropology. This association with the Division of Physical Anthropology of the National Museum has been continuously maintained by Stewart during these succeeding 30 years.

After receiving his A.B. degree from George Washington in 1927, Stewart entered The Johns Hopkins University from which he was graduated with the M.D. degree in 1931. One does not often enjoy the privilege that I now enjoy — the privilege of presenting a former pupil for such an award as this on such an occasion as this. But it so happened that Dale's first year at the Johns Hopkins Medical School coincided with my first year of teaching human anatomy, and at the same institution. I well recall how I struggled to keep ahead of the students. So I am sure that Dale learned little or nothing from me — although I know that I learned a great deal from him. He was such a good student that he found the spare time to dissect some pickled specimens of anthropoid apes, and I recall that I often dropped in on him to be educated in anthropoid anatomy.

After his graduation from medical school, Doctor Stewart returned to full-time work at the National Museum and, in 1942, on the retirement of Doctor Hrdlička, he succeeded the latter as Curator and head of the Division of Physical Anthropology, a post that he has held ever since.

In his researches, Doctor Stewart has brought to bear his superb knowledge of the human skeleton — a knowledge not only of the

normal skeleton and its variability, but also of skeletal pathology. This knowledge he has applied with his rare good judgment, intelligence, and thoroughness — as is especially appreciated by those who are privileged to know him well. Doctor Stewart has published nearly 100 papers in the field of Physical Anthropology. Of these, approximately one-third deal with the skeletal remains of pre-Columbian and early post-Columbian man in the Americas; his careful studies of the Melbourne skull and of the Tepexpan skeleton should be particularly mentioned here. His publications include numerous contributions to the physical anthropology of American Indians and Eskimos, as well as important papers on the human skull, teeth and vertebral column, and on skeletal pathology. A few of his publications deal with other primates; these include a noteworthy study on the myology of the anthropoid apes. Last, but not least, Doctor Stewart is an outstanding authority in the medico-legal field, especially with respect to problems of human identification, where he has frequently applied, with great success, the results of basic research in physical anthropology.

This does not exhaust the list of his services to physical anthropology. Upon the death of Doctor Hrdlička, Doctor Stewart succeeded him as Editor of the *American Journal of Physical Anthropology*, taking over at a critical and difficult period for the Journal. During his 6 years of editorship, from 1943 through 1948, the Journal was placed upon a firm basis, due in no small part to Doctor Stewart's energy and wise editorial policy. The foundations that he laid, and upon which Doctor Howells has subsequently built so well, have played a major role in establishing the high reputation and influence that the Journal enjoys today.

In addition, Doctor Stewart is a past president of the American Association of Physical Anthropologists, serving from 1949 to 1951. At the present time, he is a member of the Executive Committee of the Association.

In behalf of the American Association of Physical Anthropologists, it gives me great pleasure, Doctor Wenner-Gren, to present Dr. Thomas Dale Stewart for the Viking Fund Medal and Award for 1953 in recognition of his valuable contributions and for his role in helping maintain high standards in physical anthropology.

WILLIAM L. STRAUS, JR.

President



CULTURAL FACTOR IN HUMAN GENETICS.—[The “breeding isolate”] is a useful concept, and with reworking to meet the needs of human biology should yield fertile results. In basic concept, it differs but little from Boas’ idea of the population as the unit for study—the population with its traditions of assortative or free mating as instruments in the determination of its physical type. The physical anthropologists, however, have done something Boas did not do. They have taken over the hypothesis of the “breeding isolate” from the animal geneticists without serious modification, which is why its treatment as concerns man has tended to remain theoretical, deductive and undocumented. Based on assumptions concerning the presumed character and rate of change in the genetic composition of inbred or cross-bred populations, discussions of it are phrased in terms of the “evolution” of human types; and, as concerns time, of decades or centuries, as against the millennia with which the latter-day student of biological evolution deals in studying the origin of species.

The factor of tradition, which Boas handled with such sureness, is falteringly employed. This is understandable, for no theory taken over from the students of infrahuman, non-culture building forms can be expected to take the element of culture adequately into account.—M. J. Herskovits. *Franz Boas: The Science of Man in the Making*. Charles Scribner’s Sons, New York, 1953, v., 131 pp.

FIRST AMERICAN DOCTORATE IN ANTHROPOLOGY.—The years 1889 to 1892, when Boas was at Clark University, saw his productivity continue undiminished. It was here that he began his work on the problems of human growth and development, initiating what was to be one of his continuing major interests. He plotted the height-weight curves for Worcester children in a study, carried on with Alexander F. Chamberlain, that gained for Chamberlain the first doctorate to be granted in anthropology by an American university, and for Boas initiated a series of studies which provided statistical averages that for years served as a guide to the practical problems of child welfare and child development.—M. J. Herskovits. *Franz Boas: The Science of Man in the Making*. Charles Scribner’s Sons, New York, 1953, v., 131 pp.

BRIEF COMMUNICATION

RELIABILITY OF ANTHROPOSCOPIC SOMATOTYPING

J. M. TANNER

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During recent work designed to clarify the biometrical aspects of somatotyping I have accumulated some data on the reliability of anthroposcopic estimates of somatotype both between different observers and in the same observer at different times. A small part of these data has already been reported (Tanner, '52).

By "anthroposcopic somatotyping" is meant the assigning to subjects of somatotype (Sheldon, '40) ratings on a 13-point scale (1 to 7 with half-ratings) on the basis of

- (a) Inspection of standardized, properly posed photographs (Dupertuis and Tanner, '50).
- (b) Comparison of these with a key file of previously rated photographs, if necessary.
- (c) Measurement of the height and weight of the subject and entrance of a table giving height/ $\sqrt[3]{\text{weight}}$ against somatotype (Sheldon, '40, and unpublished).

The data concern three observers: Dr. C. W. Dupertuis, Miss Barbara Honeyman, and the writer. They fall into 4 groups.

1. *Dupertuis-Tanner*. In 1951 Doctor Dupertuis, in Cleveland, rated pictures of 78 healthy Oxford University students aged 17-22. The pictures were 10" \times 12" enlargements of negatives taken at 10 m using an F 24 aircraft camera fitted with a 20" lens (Tanner, '53). I had rated these pictures

about a year previously. The results of the comparison are given in table 1. In this and the subsequent tables are given the percentage frequency distribution of the differences of each component, the mean difference with its standard error (starred if significantly different from zero at the 5% level), the standard error of measurement estimated as $1/\sqrt{2} \times$ the standard deviation of the differences, and (tables 2-4) the reliability coefficient calculated as shown in the appendix.

TABLE 1

Differences in anthroposcopic somatotype ratings by two observers on 78 healthy men aged 17-22. Dupertuis — Tanner¹

DIFFERENCE IN RATINGS	-1½	-1	-½	0	+½	+1	+1½	MEAN DIFFERENCE ± S.E.	STAND. ERROR OF MEAS.
Endomorphy	0	0	22	63	10	5	0	-0.01 ± 0.04	0.26
Mesomorphy	0	12	15	50	18	5	0	-0.05 ± 0.06	0.35
Ectomorphy	0	0	9	56	31	4	0	+0.15* ± 0.04	0.24
Average	0	4	15	56	20	5	0	Average	0.28

¹To be understood as "Dupertuis minus Tanner"; i.e., the distribution is based on differences obtained by subtracting the ratings by Tanner from those by Dupertuis. This applies to tables 2 and 3 as well.

The interpretation of the standard error of measurement is as follows: in a long series of ratings of different individuals by one of the observers mentioned the difference between the ratings actually given and the "true" rating for that particular observer (i.e., the value he gets by rating a single picture many times and taking the average) exceeds $\pm 1\frac{1}{2}$ S.E. meas. in only 13% of pictures and ± 2 S.E. meas. in only 5%. (Note that this true-within-observer rating may differ from a true-between-observer rating by virtue of observer bias, or what is called drift in the appendix. By true-between-observer rating is meant the values of many observers averaged.) The S.E. meas. is in most circumstances the most useful single measure of reliability.

The reliability coefficient measures directly what proportion of the total variance of ratings of a population of pictures is due to unreliability in rating them. It measures reliability more properly than the frequently used test-retest correlation coefficient; under the present conditions, however, the two are of similar magnitude (see appendix and Tanner, '51).

2. *Dupertuis-Honeyman*. In the spring of 1953 I sent to Miss Honeyman pictures of the same 78 Oxford students aged 17-22 plus 44 others taken at the same time but of subjects aged 23-30. All the 122 had been rated by Doctor

TABLE 2

Differences in rating on 122 healthy men aged 17-30. Dupertuis — Honeyman

DIFFERENCE IN RATINGS	-1½	-1	-½	0	+½	+1	+1½	MEAN DIFFERENCE ± S.E.	STAND. ERROR OF MEAS.	RELIAB. COEFF.
Endomorphy	0	4	25	45	24	2	0	-0.02 ± 0.04	0.31	0.853
Mesomorphy	1	5	24	43	21	4	2	+0.00 ± 0.05	0.37	0.828
Ectomorphy	0	2	13	37	37	11	0	+0.22* ± 0.04	0.32	0.912
Average	0	4	21	42	27	6	1	Average	0.33	

Dupertuis two years earlier (only the 17-22 age group appears in experiment 1 as I had not at that time access to height/weight tables covering the older age range). Miss Honeyman was sent contact prints, 5" × 6", taken from the same negatives from which Doctor Dupertuis' enlargements had been made. She was aware that I had assigned ratings to some of these subjects, but not that I had a list of Doctor Dupertuis' ratings on them also. Thus in this test neither observer knew that their ratings were being compared. The Dupertuis-Honeyman differences are given in table 2.

3. *Honeyman-Tanner*. At the same time that Miss Honeyman rated the 122 pictures of experiment 2, she rated also 287 pictures of healthy cadets aged 18-20 of the Royal Mili-

tary Academy, Sandhurst, England, and 81 pictures of medical students aged 19-30 of St. Thomas's Hospital. These ratings were made from 5" \times 6" contact prints. Previously all these subjects had been rated by me, using 10" \times 12" enlargements. The Honeyman-Tanner differences for the combined material of 368 pictures are given in table 3.

4. *Honeyman-Honeyman.* The last experiment concerns the reliability of ratings of a single observer on far more difficult material than the healthy young men of the preceding studies. In the summer of 1952 Miss Honeyman somatotyped 10" \times 12" pictures of 119 female diabetic patients that I

TABLE 3

Differences in ratings on 368 healthy men aged 18-30. Honeyman — Tanner

DIFFERENCE IN RATINGS	-1½	-1	-½	0	+½	+1	+1½	MEAN DIFFERENCE ± S.E.	STAND. ERROR OF MEAS.	RELIAB. COEFF.
Endomorphy	3	12	37	35	11	2	0	- 0.28* ± 0.03	0.36	0.817
Mesomorphy	0	2	13	36	34	12	3	+ 0.25* ± 0.03	0.36	0.833
Ectomorphy	0	1	21	51	25	2	0	+ 0.02 ± 0.02	0.27	0.932
Average	1	5	24	41	23	5	1	Average	0.33	

had photographed and brought to Oregon for her to see. They were of all ages from 16 to 80, and in very various grades of health and nutrition. Many had obviously lost weight, and in only a few of these instances was there a reasonably accurate history of weights at previous ages. Under these circumstances the rater finds the height/ $\sqrt[3]{}$ weight table greatly diminished in value, though not absolutely useless. An estimate of the weight loss has to be made from the appearance in the picture, aided by the history if any, and the table entered with the guessed "normal" weight to see if the result squares with the purely anthroposcopic estimate of somatotype. If it fails to do so, one or the other estimate, of weight

loss or somatotype, must be revised; the whole process is one of visualizing the pre-diseased appearance from the remnants the disease process has left behind. This demands much more skill and experience than somatotyping healthy subjects; nevertheless a high degree of consistency can apparently be achieved by a properly trained observer. Miss Honeyman went through the diabetic series and wrote on the back of my pictures her estimate of the somatotype. I took the pictures away with me and no record of any sort

TABLE 4

Differences in ratings assigned by a single observer, Honeyman, to 119 female diabetic patients, aged 16-80 with various degrees of weight loss

10" × 12" pictures first occasion, 5" × 6" pictures second occasion,
9 months later

DIFFERENCE IN RATINGS	-1½	-1	-½	0	+½	+1	+1½	MEAN DIFFERENCE ± S.E.	STAND. ERROR OF MEAS.	RELIAB. COEFF.
Endomorphy	0	3	25	49	21	2	0	-0.03 ± 0.04	0.29	0.909
Mesomorphy	0	2	19	45	23	7	4	+0.12* ± 0.04	0.37	0.666
Ectomorphy	0	1	13	58	22	6	0	+0.09* ± 0.04	0.27	0.897
Average	0	2	19	51	22	5	1	Average	0.31	

was left with her; at the time neither of us contemplated repeating the ratings. Nine months later, however, I sent Miss Honeyman 5" × 6" contact prints of the same negatives and the results of her second ratings are compared with her first ones in table 4.

DISCUSSION

Tables 1-3 all point to the same conclusion: that trained observers using the technique of anthroposcopic somatotyping as at present formulated agree in their ratings on healthy men aged 18-30 to within half a rating on the 7-point scale in 90% of instances. In 10% of instances ob-

servers differ by as much as one rating unit; very seldom indeed do they differ more than this.

Table 4 indicates that in the much more difficult material of diseased patients of all adult ages a trained observer achieves self-consistency of just about the same degree. Differences between observers under these circumstances have not been investigated.

These figures lead to a standard error of measurement of about 0.33 units and reliability coefficients of about 0.83 for the first two components and 0.92 for the third, when the ratings cover the full range of the scale. Ectomorphy appears to be the easiest component to rate and mesomorphy the hardest.

It should scarcely be necessary to add that anthroposcopic somatotyping, like any other technical procedure, can be done reliably only after the rater has acquired some training and experience on the technique, and only on clean material, that is properly lighted and posed pictures. In this respect it differs not at all from chemical determinations on body fluids; serum cholesterol estimations for example are repeatable in skilled hands, but not in unskilled ones or on badly collected serum, as the investigation of Wooton and King ('53) most clearly showed. Each of the three observers whose results are reported here has been using the technique, off and on, for over 5 years, has rated over a thousand pictures, and has personally taken the requisite type of photographs. Probably the minimal experience required to produce ratings on normals of the reliability reported here is a few weeks' training in the laboratory, a couple of hundred practice ratings on known material, and experience in taking suitable photographs.

The systematic mean differences which occur between observers rating the same series are small but very important when comparing series from different laboratories. This observer bias is the equivalent of zero error in measuring instruments. We have no guarantee that one observer always keeps the same bias in relation to others; drift may occur

from time to time (just as it does in the estimations made by chemical laboratories), though it can be minimized by the use of key files and the interchange of specimens from one laboratory to another. A purely measuremental technique of somatotyping (which I hope shortly to make available for young men in normal health) should practically eliminate this bias.

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APPENDIX

By *unreliability* is meant the variation in replicated measurements (in this case, ratings) of the same individual (in this case, photograph). Two circumstances in which unreliability occurs must be distinguished: the *no-drift* case where the mean value of all individuals does not differ from replication to replication, and the *drift* case where the mean value does differ from one occasion of measurement to the next.

For the *no-drift case* the value of any measurement can be written $X = X_t + e$, where X_t is the "true" or stabilized value, constant for each individual (photograph, in this case) and e is the unreliability term. Then e is a random variate which we assume uncorrelated with X_t , with mean zero and variance s^2_{unr} . (In the present context s^2_{unr} , standing for variance due to unreliability, is the same as s^2_{meas} , the variance of measurement, whose square root appears in tables 1-4. In some other circumstances, however, it is convenient to consider s^2_{unr} as compounded of strictly instrumentation error called s^2_{meas} and a variation due to physiological fluctuations in the individual called s^2_{fluct} .) If two measurements have been made on each indi-

vidual s^2_{unr} is readily obtained from the set of differences D between the duplicate readings as

$$s^2_{\text{unr}} = \frac{1}{2} \frac{\sum D^2}{N} \quad \dots \dots \dots (A)$$

where N is the number of individuals. (Notice that this estimate has the precision appropriate to N degrees of freedom, not $N-1$, since the population mean difference in the no-drift case is assumed to be zero.) In the more general case, when p measurements have been taken on each individual we have the analysis of variance:

SOURCE OF VARIATION	DEGREES OF FREEDOM	EXPECTED MEAN SQUARE
Between individuals	$N-1$	$p\sigma^2_{x_t} + \sigma^2_{\text{unr}}$
Residual (within individuals)	$N(p-1)$	σ^2_{unr}
Total	$Np-1$	

Here $\sigma^2_{x_t}$ is the variance of the "true" values in the population of which the individuals form a sample, and σ^2_{unr} is the population unreliability variance. Thus it is seen that s^2_{unr} is obtained as the estimated residual mean square which in this case (but not in the drift case, see below) is the mean square within individuals. The *reliability coefficient* is defined so as to give a measure of the ratio of the variance due to unreliability to the total variance of the measurements. With reference to the analysis of variance above we have

$$r_{\text{rel}} = \frac{\text{Mean square between individuals} - \text{mean square residual}}{\text{Mean square between individuals} + (p-1) \text{ mean square residual}}$$

which substituting the estimates of mean square gives

$$r_{\text{rel}} = 1 - \frac{s^2_{\text{unr}}}{s^2_{x_t} + s^2_{\text{unr}}}$$

In the second case, *where drift occurs* and the mean value alters from occasion to occasion, we may suppose the observed measurement X to be given by $X = X_t + T + e$, where X_t and e are as before, and T is constant for all individuals on any one occasion, but varies from one occasion to the next. We define s^2_{unr} and r_{rel} exactly as

above except that now the analysis of variance appears as a two-way classification, by individuals and occasions, thus:

SOURCE OF VARIATION	DEGREES OF FREEDOM	EXPECTED MEAN SQUARE
Between individuals	$N - 1$	$p\sigma^2_{xt} + \sigma^2_{unr}$
Between occasions	$p - 1$	
Residual	$(N - 1)(p - 1)$	σ^2_{unr}
Total	$Np - 1$	

If in this case only two occasions are involved and s^2_{unr} is calculated from the differences D , the formula is

$$s^2_{unr} = \frac{1}{2} \left(\frac{\Sigma D^2 - \frac{(\Sigma D)^2}{N}}{N - 1} \right)$$

since the population mean difference is not assumed to be zero.



INSTRUCTIONS FOR EXPOSING AND DEVELOPING X-RAY FILMS FOR BONE DENSITY EVALUATION. By Walter N. Brown, Jr. Bone Density Research and Evaluation Center, School of Chemistry and Physics, The Pennsylvania State College, State College, Pennsylvania. 19 pp. 1953. — The technique of bone density measurement, extensively developed by Doctor Mack and Doctor Brown, is here reviewed in a simplified how-to-do-it form. Technical considerations (x-ray film, processing, etc.) as well as the use of the ivory ladder are given primary consideration. Theoretical aspects and the fact that all evaluations are given in terms of ladder thicknesses rather than calcium equivalents are not dealt with at length. Nevertheless it should be pointed out that bone density is an important and little-investigated variable about which we should like to know more.

COHUNA CRANIUM REINVESTIGATED.—The only essential facts which emerge [from chemical analysis] are that the Cohuna cranium is unrelated to other skeletal material in the same stratigraphic horizon, it is an intruder, and it seems to be derived from a previous granitic habitat. A further fact confirmed by this examination is that the incrustation on skeletal material and the mineralization of the bone itself are two separate processes and must be treated accordingly. . . .

If the skull underwent mineral impregnation in the Mt. Hope granitic area, and was subsequently carried by flood waters to the site of its discovery, all the physical and chemical observations on the cranium would be explained. There is no absolute proof, the evidence is circumstantial, but no other practical explanation fits all the observations. . . .

In terms of such an interpretation, and the necessary lapse of time involved, the cranium probably has at least moderate antiquity.—N. W. G. Macintosh. The Cohuna cranium: Physiography and chemical analysis. *Oceania*, vol. 23, no. 4, June, 1953, pp. 277–296.

SELECTION VS. GENETIC DRIFT.—Some traits, of course, must originally have been fixed by selection. Dark skin is probably a biological advantage in the tropics, while pale skin may be an advantage in weaker northern light. The same may hold for kinky hair as against straight hair, for dark eyes as against light eyes, and the like. Many possibilities of this kind have been suggested in a recent book, *Races: A Study of the Problems of Race Formation in Man*, by Carleton S. Coon, Stanley M. Garn and Joseph B. Birdsell. I remain skeptical when I think of the prevailing hairlessness of man in many regions where more body hair would have helped to keep him warm. I am particularly skeptical of any selective advantage in blondness, “the most distinctive physical trait or group of traits shown by Europeans.” It seems more likely that these traits confer no advantage to speak of, in Europe or elsewhere. I would add that if blonds had been eliminated by selection in other parts of the world, and if a blond type happened by genetic drift to become established in Europe, then it could have persisted and spread in large populations and given rise to the present racial distribution of the blond caucasoid or “Nordic” man.—H. Bentley Glass. The genetics of the Dunkers. *Sci. Am.*, vol. 189, no. 2, Aug., 1953, pp. 76–81.

REVIEWS

DATING THE PAST; AN INTRODUCTION TO GEOCHRONOLOGY. By Frederick E. Zeuner. 3rd edition, revised and enlarged. 1952. xx + 495 pages and 24 end-plates. Methuen and Co., Ltd., London.

The third edition of this book includes material from the literature up to December, 1951; the bibliography has thus been increased to 1117 references (650 in the first edition of 1946). Some new material has been incorporated into the text, but much has been added to the appendix (20 pages in this edition, 12 in the second edition of 1950). Otherwise, the same format and organization has been retained throughout. As in earlier editions, the Villafranchian has been assigned a pre-Pleistocene date although abundant evidence warrants inclusion of this stage in the Lower Pleistocene (formally agreed on at the 18th International Geological Congress held in London in 1948). Thus, many stratigraphic units referred to the late Pliocene are in reality of Pleistocene age. Attention is particularly focussed on Europe, and fairly brief treatment given Asia and Africa although the Pleistocene sequence is now better known in both continents. The Heidelberg mandible is still regarded as of first interglacial age but this dating is questionable and the fauna suggests it to be second interglacial. The Keilor skull cannot be accepted as third interglacial, but is more likely post-Pleistocene. The supposed flint industries from the East Anglian Crag and sub-Crag deposits, and the Cromer Forest Bed as well, are of questionable human manufacture; most probably they are the result of natural agencies. Questions might be raised on a number of points of dating in the European sequence (e.g., the very doubtful first interglacial age of the Abbevillean). The first C^{14} dates might better have been included in the section on the post-Pleistocene rather than in the section on measurement of geologic time. Since the war, so much new evidence has been published, and so much of the older evidence reevaluated, that it is hoped any future edition might be entirely rewritten. "Dating the Past" is an extremely useful book for its excellent survey of a vast and difficult literature and is still the standard reference to the field of geochronology.

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BLOOD GROUPS IN MAN. By R. R. Race and Ruth Sanger. Blackwell Scientific Publications, Oxford, England. 1950. xv + 290 pp.

This book is by far the best introduction to, and general up-to-date account of, the subject of blood groups with which the reviewer is familiar. The treatment is clear and concise, yet amazingly complete. There is no dead wood, and every page could be read with profit.

The authors, who are among the most active and productive workers in the field, and who have contributed notably to recent advances in knowledge (we may mention C^w, Lutheran, Kell and Levay), write with the assurance born of authoritative knowledge, and the clarity we have come to expect of British scientists.

As is natural, the majority of the book is devoted to the modern work, and the subject of Rh occupies 95 pages; 39 pages are devoted to still more recent discoveries. Nevertheless, the older ABO and MN systems are fully treated, the expansion of the MN system due to the discovery of anti-S is explained, and the anti-s serum (which has since been found) "confidently predicted."

In the chapters on Rh the authors present both the Wiener and the Fisher-Race notations fully and in a most impartial manner.

Methods of testing are well discussed, although the book does not purport to be a laboratory manual, and the clinical and medico-legal aspects of the subjects are clearly presented.

Although no advanced mathematical methods are used, the book is noteworthy for the clearly presented methods of calculation of gene frequencies, "usefulness" of the various systems, and other such problems. The authors are obviously well equipped themselves to deal with these subjects, and they have had in addition the privilege of consultation with R. A. Fisher, the sun of whose genius has "illuminated the English blood group work."

This book, together with the forthcoming companion volume on the distribution of the human blood groups by Dr. Mourant, constitute a pair which no physical anthropologist who makes use of genetical methods can afford to be without.

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School of Medicine

ADVANCED STATISTICAL METHODS IN BIOMETRIC RESEARCH. By C. Radhakrishna Rao. John Wiley & Sons, Inc., New York, N. Y. 1952. 390 pp.

Until roughly 30 or 40 years ago the development of biometry and physical anthropology had this in common: certain pioneers in sta-

tistics (Quetelet, Galton, Pearson) were deeply concerned with anthropometric materials and anthropological problems. But since about 1918, when R. A. Fisher took the post of statistician at the Rothamsted Agricultural Station, biological statistics has become more and more concerned with experimental materials and designed problems. Thus there has developed a gap between the interests, problems and materials of anthropology and modern biometry. Most contemporary biometricians show little active interest in the traditional data and problems of anthropometry. "The statistician is no longer an alchemist expected to produce gold from any worthless material offered him. He is more like a chemist capable of assaying exactly how much of value it contains, and capable also of extracting this amount, and no more" (Fisher).

Perhaps because C. Radhakrishna Rao — while taking advanced training in mathematical statistics — worked as a research assistant in the Anthropological Museum at Cambridge, his present book has a vicarious significance for physical anthropology. It is the first treatise on mathematical statistics in nearly 50 years in which the illustrative problems and materials are mainly those of anthropology. Rao's book is packed with examples of the quantitative analysis of data on man, mainly physical man, and mainly his bones.

It is a commentary on the intellectual status of anthropometry that statisticians with no training in anthropology can understand Rao's book, but anthropologists with no training in statistics cannot. The title is accurate in containing the adjective "advanced." It is a tough book. But nearly all of the 390 pages are pertinent directly to the analysis of anthropological materials. For a medium-sized book, this work contains not only an impressive amount of statistical theory but also a large number of problems worked in full to illustrate computational methods.

The text is divided into 9 chapters, the first being devoted to procedures in modern algebra, especially matrices. The second chapter takes up binomial, multinomial, Poisson, normal, gamma, beta, Cauchy, and Personian P_λ distributions. The presentation of these distributions is concise; non-statistical readers will need to supplement the material given by Rao with the fuller treatment afforded by other statistical works. Chapter three deals with least square methods of estimation, introduces sampling theory with a discussion of "Studentization" and goes on to tests on linear hypotheses. The 4th chapter gives an introduction to general theories of estimation, maximum likelihood and certain other methods of deriving asymptotically best estimates. Problems of specification and homogeneity are considered in chapter 5. Tests of homogeneity of variances and covariances discussed in chapter 6 are preliminary to a detailed exposition of multivariate analysis in chapter 7. Chapter 8 considers methods

of minimizing the errors of classification, and the problems of assigning an individual to one of several populations to which he might belong is covered in detail in chapter 9. These last methods have been much advanced by contributions from the Indian Statistical Institute, Calcutta, where Rao is Professor of Statistics.

The book is well printed. The few errors in the text do not diminish its general utility. The statement (p. 33) on the sum of two binomial variates is not sufficiently restricted and the statement (p. 36) on the sum of Poisson variates is unduly restricted. The definition of the partial correlation coefficient (p. 69) is unusual as is the definition (p. 144) of a minimal set of sufficient statistics. The text is confusing (p. 276) on the difference between fiducial limits and confidence intervals. Rao's consistent use of pivotal reduction of matrices keeps the text compact, but for some problems other methods, for example triangular reduction, provide more computational economy. Anthropologists would benefit had the book contained a discussion of the problem of scale and of transformations in scale, and had it used more genetically oriented illustrations.

The last two chapters (about one-third of the book) on statistical inference applied to classificatory problems is the type of statistical procedures which are required in order to make objective interpretations of the relationships of human populations using anthropometric data. It seems likely that procedures of this sort, together with a genetic interpretation of quantitative variability in man, and in association with full use of such gene frequency information as can be made available, could achieve one of the central objectives of physical anthropology — a genetic classification of the living varieties of man.

J. N. SPUHLER

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RACE CROSSING IN MAN: THE ANALYSIS OF METRICAL CHARACTERS. By J. C. Trevor. 45 pp., 1 plate, 1 figure. Cambridge University Press, New York. 1953. \$2.50.

In this finely printed Eugenics Laboratory Memoir XXXVI from the University of London, Trevor brings together the published metric observations on hybrid groups (American Negroes, Jamaican "Browns," Half-Blood Sioux, Ojibwa-Whites, Yucatecans, Rehoboth Bastards, Kisar Mestizos, Norfolk Islanders, and Anglo-Indians) and compares these with the anthropometry of the respective "parental" populations. The methodological difficulties inherent in a study of this sort in view of the limitations of the available material, are clearly perceived and enunciated. This aspect of the memoir is itself a per-

tinent contribution. Yet, although "At first sight it seemed quite probable that the material would be too defective to yield conclusions of any value. . . . Actually those arrived at are so consistent that it can be safely assumed that its manifest defects are of less consequence than was feared."

The author's major "conclusions," based on a statistical analysis of the material, are: (1) "Comparisons of the mean measurements of metrical characters . . . possibly suggest that the average for a crossed population always tends to lie between those of the parental populations in cases where the latter themselves differ significantly" (p. 28); (2) "Generalization is difficult, but all the evidence concurs in showing that the populations derived from the crossing of distinct racial stocks are not distinguished by a particularly marked degree of variation" (p. 37); (3) "On the whole, it is safe to conclude that most measurements of bodily proportions found in the literature are not sufficiently reliable to provide valid comparisons of hybrid with other populations, and in particular it is unsafe to conclude that the variabilities for them would yield any different general conclusions from those based on head measurements" (p. 42); (4) "It can be stated categorically that the material available does not suggest that the distributions of metrical characters in populations derived from the crossing of distinct racial groups are in any way peculiar when compared in populations of unmixed origin" (p. 43).

In a prefatory note, Prof. L. S. Penrose observes that "visible and metrical features of mankind" are not as directly controlled by genes as, for example, are the blood antigens; and that "metrical physical differences between tribes or populations cannot always be assumed to be genetical in origin." This assumption, usually implied, is pretty common in the anthropological literature. Indeed, to the reviewer's mind, within limits the assumption seems reasonable, i.e., similarity between peoples in metric *and* morphological characters (e.g., skin color, hair form) at least suggests genetic relationship. Yet it must be said that the assumption as such has received little attention or testing: Which, if any, physical measurements and/or morphological observations provide a reliable index of genetic affiliation? How close a genetic affiliation (familial, population, racial)? It may be recalled that Franz Boas, and no doubt others, long ago emphasized the need for genetic studies of single traits in man; Boas also urged the study of whole families and showed how the statistical tool of variance could then be a measure of the degree of homogeneity of a population.

A word more may be said about variability. Plainly the extent and kind of biological miscegenation among man in large measure depends on, and is explained by, the past history and present socio-

logical context of the populations involved. Trevor touches upon these facets of the problem. Whether more could have been said on the basis of the available material, I am not sure. Trevor remarks that "A much greater number of well-recorded characters for a single hybrid series and for two large series relating to the parental populations from which it was actually derived would be of far more value for the quantitative investigations of these matters than all the material bearing on the topic which is at present available" (p. 31). One might add to the statement that the cooperation of a sociologist or social anthropologist in such a study would probably make it much more meaningful.

The frontispiece, a reproduction of an unusual portrait of Blumenbach in whose memory the memoir is dedicated, enhances this stimulating and provocative contribution.

MARCUS S. GOLDSTEIN
U. S. Public Health Service



LE RAZZE E I POPOLI DELLA TERRA. By Renato Biasutti. Vol. I. *Razze, Popoli e Culture*. 2nd. Ed. xi + 723 pp., 16 color plates, 495 illustrations and 38 maps. Unione Tipografico-Editrice Torinese. Torino, 1953.—This is the first of 4 volumes planned to revise and enlarge the three volumes of the first edition published in 1940. Biasutti has the aid of M. Bartoli, R. Battaglia, R. Corso, G. Genna, P. Graziosi, S. Sergi, C. Tagliavini, G. Vidossi in their writing on special sections. Over half of the coverage is of direct interest to physical anthropology, with the remainder being on linguistics, technology, folklore, cultural classifications and related subjects. Some of the chapters are new, much of the illustrative material is new and portions of the first edition have been expanded in part. While this volume could never claim to be part of a "new" physical anthropology, it is a compendium of some materials, references and ideas which frequently appear only in the European literature. Unfortunately the bibliography is very limited in recent references and the organization and illustrations make the volume more appealing to the searcher for exotica than to the systematic scholar.

PROCEEDINGS
OF THE TWENTY-THIRD ANNUAL MEETING
OF
THE AMERICAN ASSOCIATION
OF PHYSICAL ANTHROPOLOGISTS

The twenty-third annual meeting of the Association was held on Friday, Saturday, and Sunday, March 26, 27, and 28, at the Fels Research Institute, Antioch College, in Yellow Springs, Ohio, at the invitation of those institutions. After a welcoming address by Dr. Lester W. Sontag, director of the Fels Research Institute, the scientific session began on Friday morning with a symposium on "bone age" (sequence of osseous maturation) organized by Dr. Stanley M. Garn who also arranged the whole program and headed the local committee. At 3:00 P.M. this was followed by a visit to the Wright Air Development Center, Wright-Patterson Air Force Base, for a demonstration of the applications of physical anthropology to the designing of airplane cockpits, control-sticks, instruments, pressure-suits, oxygen masks, prone-position "beds," and seats. H. T. E. Hertzberg, assisted by Frank P. Saul, conducted this demonstration after a welcome to the group from Colonel Jack Bolerud. Especially interesting were methods of determining convenient limits of hand and arm joint motion and seat pattern (ischial tuberosity pressure), the use of slit-beam lights to map contours of face or body photographically, and the use of strain-gauges to measure pressure exerted. Air Force busses took the group to Wright Field to inspect F-86 jet fighter and B-47 jet bomber, giving members a graphic impression of spatial and kinetic difficulties in matching people to modern high-speed aircraft.

The annual business meeting and smoker were held Friday evening at the Hotel Shawnee. Ninety-three people attended the meetings, including 54 members.

On Saturday afternoon Dr. Lester W. Sontag was host to the members of the Association and guests at the cocktail hour in the Fels Nursery School, one of the rooms used that morning for Demonstrations. The annual dinner followed, attended by 78 people, at the Antioch College Tea Room. The guest speaker was Dr. Paul Fejos, director of research at the Wenner-Gren Foundation for Anthropological Research. He spoke on "eyeglass" projects in anthropology as he could see them and help to develop them from his window-seat in the Foundation. Pointing to the growth of physical anthropology since the almost explosive changes in attitude of 12 years ago, he stressed the part played by this science in the 154 grants (to 64 institutions in 19 states and 14 foreign countries), 7 summer seminars, and two major symposia supported by the Foundation, and the advantageous ways in which physical anthropology, primarily a biological science, has drawn on its sibling social sciences in advancing. Doctor Fejos instanced the whole stimulus and development of Libby's C_{14} method of dating, with its support and encouragement from the Foundation, as a proof of the value of cooperation between fields and of the importance of timing in growth of ideas. The use of the proper "eyeglass," or understanding proper timing, is therefore the key both to planning of cooperative research and to skilled use of the experimental and historical methods in analyzing and then solving the new problems in our science. After the Sunday sessions the program was concluded by a tour of the many laboratories and facilities for the study of human growth from all possible aspects at Fels.

BUSINESS MEETING, MARCH 26, 1954

President William L. Straus, Jr., opened the business meeting with announcement of the committees for the coming year. The Nominating Committee includes Dr. Wilton M. Krogman

(chairman), Dr. M. S. Goldstein, and Dr. Fred Thieme. The 1954 Viking Fund Award Committee will be under chairmanship of this year's winner, Dr. T. Dale Stewart, assisted by Dr. W. L. Straus, Jr., and Dr. E. A. Hooton.

After the minutes of the 22nd annual meeting of the Association had been voted approved as printed in the Proceedings, A.J.P.A. n.s. 11: 244-249, 1953, the Secretary reported on membership. After referring to the continued acceleration in growth of the Association (1930, 109 members; 1942, 153; 1952, 300; 1953, 342) the Secretary pointed out that the 1953 figure includes 18 inactive Life Members (7 other Life Members pay dues), 13 still with dues unpaid, and 34 taken in by the Executive Committee under the revision of Article V of the By-Laws printed in the Proceedings of the 22nd meeting, and submitted for ratification as follows:

David Ames	Elli Jensen
Paul T. Baker	Myron Klatsky
Preben Boesen	Howard Levene
John W. Chaffee	D. N. Majumdar
Helen J. Colby	Donald Marshall
Paul Colonna	Joseph Milgram
Mary R. Crawford	William Nussbaum
Charlene Craft	H. W. O'Dell
Leslie C. Dunn	Robert E. Popham
Mary F. Ericksen	Frank P. Saul
Tsunetaro Fujita	Roy T. Simmons
Roger Gerry	William H. Sheldon
Ruth V. Harper	Daris Ray Swindler
Walter F. Harper	James M. Tanner
Lueile E. Hoyme	William J. Tobin
Vilma R. Hunt	Ralph J. Wedgwood
Franjo Ivanicek	Charles B. White

These were elected unanimously as were also the following 8 candidates newly proposed by the Executive Committee:

Raymond S. Baby	Rupert Murrill
Julian Granberry	Lawrence Oschinsky
Bengt Lindegard	Ailon Schulman
Lois Wells Mednick	Fred Silverman

The Secretary noted that the Executive Committee feels strongly that though we should expand the supporting body of the Association we should not propose for membership

any single person who is not truly interested in the advance of physical anthropology as well as competent and qualified to join. President Straus more specifically asked members not to submit names of candidates for membership without including full supporting data covering at least the minimum requirements for membership in order that the Executive Committee may have necessary knowledge.

The Secretary reminded the members that since last summer the Association has been an affiliate of the American Association for the Advancement of Science as part of Section H, sending two representatives to the AAAS Council, so that physical anthropologists who are not AAAS members may join it directly rather than through the AAA or by individual nomination. Our representatives to the AAAS are Dr. Montagu Cobb and Dr. W. W. Howells. Dr. Gabriel W. Lasker, Secretary of Section H, announced that the AAAS meeting next Christmas would be in Berkeley, Calif.

Announcing with sorrow the deaths of 4 members, Dr. R. E. G. Armattoe, Dr. Ralph Linton, Dr. H. C. Moloy, and Dr. Paul Reiter, the Secretary commented on their contributions to our field although they were not primarily physical anthropologists. Doctor Armattoe, a British subject, worked in Ireland and West Africa. Doctor Linton, one of America's great anthropologists in the old, pre-specialist, tradition, studied zoology first at Swarthmore before going on to University of Pennsylvania and Harvard for graduate work in all fields of anthropology. Although his career (at Field Museum, Wisconsin, Columbia, and Yale) included an amazing coverage of archeology, ethnology, and social anthropology in field work, museum work, and teaching syntheses he also developed and spread to others an intense interest in human biology, especially in diet in relation to growth and ecology. Doctor Moloy, as a physician, helped to revolutionize x-ray study of the pelvis. Doctor Reiter, though trained primarily as an archeologist and ethnologist in the Southwest U.S.A., studied physical anthropology at the University of California, was in charge of Army programs in physi-

cal anthropology (Chemical Warfare series at M.I.T.), and trained several graduate students in physical anthropology. The Association wishes to express its deep sympathy with the wives and families of these men.

The reports of the Treasurer and of the Auditing Committee were read and moved accepted by Dr. E. E. Hunt.

TREASURER'S REPORT

Prudence Bond (remaining principal)	\$ 75.00
U. S. Savings Bonds (maturity value)	\$3,000.00
	<u>\$3,075.00</u>

Bank balances December 27, 1952, in Fidelity-Philadelphia Trust Co:

Savings account	\$2,000.00
Checking account	669.31

Receipts:

Annual dues	\$3,094.93
Postage from foreign members	25.15
Sale of STUDIES	38.00
Annual dinner	27.25
Sale of Hrdlička's manual (revised by Dr. T. D. Stewart)	10.00
Prudence Bond repayment	25.00
Interest on Savings account	18.84
	<u>\$3,239.17</u>
	\$5,908.48

Expenditures:

To Wistar Institute (subscriptions)	\$2,270.00
To Wistar Institute (Proceedings)	66.87
To Wistar Institute (program)	61.92
To Bertram Kraus (newsletter)	69.91
To Penn-Sheraton (annual dinner)	26.30
Secretarial expenses	184.48
Dues overpaid and refunded	5.50
Foreign members mailing	28.00
Bank, exchange charges	1.05
	<u>\$2,714.03</u>

Bank balances March 22, 1954:

Savings account	\$2,018.84
Checking account	1,175.61
	<u>\$5,908.48</u>

Respectfully submitted
J. LAWRENCE ANGEL, Treasurer
March 22, 1954

Certified to be as stated above.
March 26, 1954
F. CLARK HOWELL
RUSSELL W. NEWMAN
Auditing Committee

The Editor of the AJPA, Dr. W. W. Howells, reported on volume 11, new series, pointing out that this was actually the 40th volume since the founding of the Journal, since there had been 29 volumes in the original series. Volume 11, for 1953, contained 612 pages, a larger amount than usual, through the courtesy and generosity of The Wistar Institute. Because of an unusual number of long papers the volume contained only 30 articles apart from book reviews. During the year, 17 articles were returned to their authors for various reasons, of which at least 5 were subsequently published elsewhere. In addition, 12 articles were made available (with the consent of their authors) to the *American Anthropologist* in order to provide representation in that journal for physical anthropology, and to *Human Biology* to provide material at a critical juncture when the President, Doctor Straus, and the Editor had persuaded the Johns Hopkins Press to keep *Human Biology* going and had asked Doctor Lasker to become its editor. The report of the Editor was accepted on Doctor Garn's motion.

The Secretary opened discussion of the Association's relations with other organizations by pointing out that *Human Biology* is now underwritten by Wayne University, making possible its continued appearance, and that its editor, Dr. Gabriel Lasker, deserves the congratulations of the Association. Asked what the Association can do to further this journal's advance, Doctor Lasker remarked that negotiations for transfer of the journal from the Johns Hopkins to the Wayne University Press were almost complete and that though there had been in 1953 an increase in number of subscribers as well as of pages (460 pp.) there were only 60 private (non-institutional) subscribers many of whom were members of the AAPA. Accordingly support from the Association itself and from individual members would be appreciated. Subscription is \$5.00. The 1953 volume, with 23 original articles, shows that there is room for another journal in this general field, not competing with the coverage of the AJPA or of *Science*.

The Secretary announced the recent appointment of our Association's President, Dr. William L. Straus, Jr., to the editorial board of the American Association for the Advancement of Science which has space available for short and important articles in *Science* or longer and more popular articles in the *Scientific Monthly*. Dr. Raymond Taylor will circularize the membership of the AAPA, noting that Doctor Straus, representing the Association, will sponsor any member who wishes to join the AAAS. As Secretary of Section H Doctor Lasker has stressed that the AAAS has an excellent system of publicity for papers given at its meetings. In this connection Doctor Straus mentioned the conflict between Section H and the AAA when both met at Christmas time, noting that Section H tended to suffer although the AAAS represents American Science as a whole.

The Secretary reported that the next meeting of the American Anthropological Association would be in Detroit at Wayne University and that President J. O. Brew of the AAA would like to cooperate with the AAPA in holding a symposium on physical anthropology. It was uncertain if the meeting would be at Christmas or shortly after Thanksgiving (Lasker). Dr. Fred Thieme, noting that his Michigan colleague Dr. David Aberle will be program chairman, proposed a symposium on human evolution in the light of recent finds, if possible with foreign as well as American discussants. Pointing out that general anthropologists would enjoy such a program Dr. S. L. Washburn thanked Doctor Howells for papers transferred to the *American Anthropologist* and regretted deeply the loss of Dr. Ralph Linton, who always kept up interest in physical anthropology. President Straus applauded the suggestion of a Symposium at the AAA meetings but warned against competition with Section H of the AAAS if we sponsor the former officially. Asking Doctor Lasker what attendance he expected at the Berkeley meeting of the AAAS (6-8,000 Doctor Lasker replied), Dr. F. C. Howell stressed the need to sponsor the Detroit symposium if it has an international attendance and Dr. W. W. Howells noted the tradi-

tion of co-sponsored symposia. Doctor Straus closed discussion with the decision to appoint a committee to undertake symposium arrangements with the AAA.

After receiving the Executive Committee's congratulations on his editorship of the Newsletter, Dr. Bertram Kraus stressed his two needs: more replies to his requests for news and more money for publication. In response to Doctor Kraus' request for suggestions, Doctor Angel proposed wider functions for the Newsletter since it goes to foreign members and others who cannot easily attend annual meetings, and Doctor Lasker pointed out that this means of communication becomes much more important now, since the current issue of the Yearbook is the final one. Doctor Straus, accordingly, proposed that the Newsletter include a bibliography of what all the members are publishing. After discussion of timing (Doctor Washburn), and more specific news categories to overcome respondents' modesty (Doctor Stewart), Doctor Garn asked why response to the request for news was not better last year. Doctor Dempster replied indirectly, noting that even a single item on what a colleague was doing in original work had been invaluable in saving time as he himself developed a new project. After a proposal of thanks moved by Doctor Meredith, Dr. C. E. Snow moved that the Association appropriate \$125 for the Newsletter to allow Doctor Kraus to include bibliographic data for the preceding year, and both motions were passed.

The Secretary reported that the Wenner-Gren Foundation for Anthropological Research had announced on March 5, 1954, the launching of a combined Yearbook of Anthropology to cover all fields of anthropology. In this the place of our science remains to be worked out. Doctor Lasker as original organizer of the Yearbook of Physical Anthropology and the Association as a whole should feel flattered at this extension of the idea, as well as grateful to Dr. Paul Fejos and the Wenner-Gren Foundation for support of the original Yearbook and Summer Seminar series. Doctor Spuhler, editor of

the Yearbook for 1952, noted that this, the last issue, is in press.

Dr. S. L. Washburn, chairman of the Nominating Committee (assisted by Dr. E. A. Hooton and Dr. B. S. Kraus), noted that the committee had received 49 cards with nominations from the membership, representing a good proportion of the professional physical anthropologists, and presented the unanimous slate of Dr. Montagu Cobb for vice-president (two-year term) and Dr. James Spuhler for executive committee member (three-year term). The two nominees were elected unanimously.

The Resolutions Committee read the following report, accepted by the membership on motion of Dr. Mildred Trotter:

1. Be it resolved that the Association express its gratitude and appreciation to Dr. Douglas McGregor, President of Antioch College, and to Antioch College for their part in making its facilities available to us.

2. Be it also resolved that the Association make known its appreciation to Dr. Lester W. Sontag, Director of the Fels Institute, and to the staff of this Institute, for their hospitality to the Association.

3. Be it further resolved that the Association voice its thanks to Dr. Stanley M. Garn, Chairman of the Physical Growth Department of the Fels Institute for its skillful and hospitable management of the transportation, housing, programming, and itinerary of the membership gathered at the 23rd meeting of the Association.

4. Be it further resolved that the Association express its appreciation to Mr. H. T. E. Hertzberg and the other anthropologists associated with the Aero Medical Laboratory, Wright-Patterson Air Force Base, for their courtesy in conducting the members of this Association through their installation.

5. Be it also resolved that the Association thank Dr. Paul Fejos and the Wenner-Gren Foundation for their continued support of physical anthropology in general, and especially for their help in making possible the Wenner-Gren Summer Seminar in Physical Anthropology, held at the Forsyth Dental Infirmary for Children in Boston, Massachusetts, on June 21-24, 1953.

6. Be it further resolved that the Association extend its thanks to Dr. Wilton M. Krogman for his able chairmanship of the 1953 Wenner-Gren Summer Seminar in Physical Anthropology.

7. Whereas Dr. William W. Howells has continued as editor of our official publication, the *American Journal of Physical Anthro-*

pology, the Association hereby records its continued appreciation of his editorial skill, and especially of his fruitful collaboration with the editors of *Human Biology* and of the *American Anthropologist*.

8. Whereas the Association has lost 4 of its very valued members in the past year: Dr. R. E. G. Armattoe, Dr. Ralph Linton, Dr. H. C. Moloy, and Dr. Paul Reiter; be it resolved that the Association extend its sincerest sympathy and condolences to the bereaved families.

Respectfully submitted,

EDWARD E. HUNT

E. CARL SENSENIG

For its 24th annual meeting the Secretary announced that the Association is invited by Dean George A. Bennett of the Jefferson Medical College, and by Dr. Froelich Rainey of the University Museum, to meet in Philadelphia. Since Jefferson has invited the American Association of Anatomists to meet at their institution during the latter part of the week before Easter week, April 7, 8, and 9, 1955 (and the invitation has been accepted), the AAPA might conveniently meet just before the anatomists. Doctor Kraus suggested Tucson, Arizona, as a site for a future meeting, pointing out that 530 AAA members met there at Christmas, 1953.

The scientific part of the program included the following papers:

SYMPOSIUM ON SEQUENCE OF OSSEOUS MATURATION
("BONE AGE")

1. *Prenatal chondrification and ossification in the hand and foot.* Ronan O'Rahilly and Ernest Gardner, Department of Anatomy, Wayne University.

The initial appearance of chondrification centers for the skeletal elements of the hand and foot has been observed in human embryos between 15 and 20 mm C.R. The findings are compared with those of Lewis, Bardeen, and Senior; further work will be necessary in order to correlate Senior's sequence with Streeter's developmental horizons. The appearance of ossification centers has been examined in serial sections of hand and feet of human fetuses. The results obtained by the histological approach are compared with those of Noback and Robertson who used the alizarin red technique.

2. *The assessment of skeletal maturation, through the use of the first 67 centers to appear.* Lester W. Sontag, Fels Research Institute. (No abstract.)

3. *Evidence for genetic control of the time of calcification of the early appearing centers.* Albert Breithach, Public Health Office, Düsseldorf, and S. M. Garn, Fels Research Institute. With comments on the genetic method by David C. Rife, Institute of Genetics, Ohio State University. (No abstract.)

4. *Sequence of age changes in the joints of the sternum.* T. Dale Stewart, U. S. National Museum.

T. Wingate Todd recognized that the joints of the sternum held possibilities for age determination. However, being of the opinion that the pubic symphysis was a better indicator of age than any other part, he passed over the sternum in favor of describing the symphysis. Resulting fixation of attention on the symphysis seems to have removed incentive for further study of the sternum.

The joints of the sternum are of two types: diarthrodial and synchondrodial. These two types occur in juxtaposition at the supero-lateral angle of the manubrium where the clavicle and first rib articulate. This peculiar arrangement and the differences in joint metamorphosis involved, offer an array of features for age correlation. There are additional changes of this nature at the intersternal joints.

The material on which the present study is based comes from archeological sources. Age at death is unknown and must be inferred from the symphysis pubis and other indicators. This being the case, only the sequence of changes in the sternum will be dealt with. Definite age limits will have to be placed on the changes by someone having access to dated material.

Recovery of the whole sternum in archeological work is not as frequent as could be wished, but may increase as special attention is devoted to it. In any case, the addition of another bone to those now yielding evidence on age is highly desirable.

5. *Clinical experiences in the assessment of skeletal maturation.* Frederic N. Silverman, M.D., The Children's Hospital, Cincinnati, Ohio.

The assessment of skeletal maturation by roentgen techniques is modified by disease factors as well as anatomical variations. In skeletal dystrophies, the failure of appearance of an ossification center does not necessarily indicate retardation of maturation; the distorted configuration of secondary ossification centers in skeletal dystrophies does not permit comparison with normal standards. The frequent appearance of pseudo epiphyses in hypothyroid children, as well as children with dystrophies may require some explanation which is not currently available. Local acceleration of epiphyseal development may occur as a result of local inflammatory reaction due to infection or hemorrhage (tuberculosis, chronic osteomyelitis, hemophilia). Disparities between the maturation of the carpal bones and of the metacarpal-phalangeal secondary ossification centers merits serious consideration of Robinow's suggestion that separate standards be devised for these two groups of determinants. Endocrine disturbances produce variable alterations in the epiphyseal developmental pattern; the appearance of a large pituitary fossa in certain cases of hypothyroidism merits investigation. Correlation of dental maturation and skeletal maturation is not close; skeletal maturation demonstrates much wider deviations from normal than does dental

maturation in various pathologic endocrine states. The question is raised of the factors controlling the development of teeth in a teratoma as opposed to the development of teeth in normal sites.

6. *Some interrelationships of growth and skeletal status in children.* Pauline Beery Mack, College of Household Arts and Sciences, Texas State College for Women, Denton, Texas. (No abstract.)

7. *An evaluation of two skeletal age determinants: the morphology of the symphysis pubis and cranial suture closure.* Sheilagh Thompson Brooks, Department of Anthropology, University of California, Berkeley. (No abstract.)

8. *Sex differences in skeletal material.* Fred P. Thieme, Department of Anthropology, University of Michigan.

Comparisons were made of measurements taken on 200 known sex U. S. Negro skeletons (101 females, 99 males) from the Terry collection of Washington University to see which were the best indicators of sex. Femur length, femur head diameter, humerus length, epicondylar diameter of humerus, clavicle length, sternum width, pubis length, ischium length were all measured and the opening of the sciatic notch observed. Of any single measurement, sternum width shows the greatest "coefficient of divergence," however, the greatest "t" value comes from femur head diameter differences ($t = 16.2$). Using the ischium/pubis index, 80% of the sample was properly segregated, and of the 40 individuals still uncertain (between I/P index 85 to 92) all but two were accurately sexed by using the diameter of femur head (under 44 mm—female) which gives a final discrimination of 99% of the original sample. Using femur length (under 44 cm is female) 5 were unsexed; for sternum width (female under 34 mm) 7; for epicondylar width of humerus (female under 60 mm) 5; for ischium length (female under 85 mm) 6; for humerus length (female under 31 cm) 5; for clavicle length (female under 14.5 cm) 4; and for sciatic notch there were 9 uncertain using our observation records. To conclude, by first using I/P index and then femur head, 99% of adult Negroes can be accurately sexed which gives sufficient probability that any single specimen, or population, can be accurately sexed by this method.

9. *Some problems in interpretation of Greek skeletal material: disease, posture, and microevolution.* J. Lawrence Angel, the Daniel Baugh Institute of Anatomy of the Jefferson Medical College, Philadelphia.

How sensitive to environment are chronic bone diseases? How accurately does bone fossilize physiology? How effective is social selection as opposed to natural selection?

Vertebral osteoarthritis (U.S.A. living male incidence 20%) decreases 70% in prehistoric times to 40% in historic times despite correlation with age (age at death rises). Cranial osteoporosis, causable by dietary lack and/or anemia (thalassemia here?), shifts from 25% to zero (Classical times) to 33% in Turkish times (10% in U.S.A. dissecting room skulls).

Greek environment demands an efficient mountaineer's or skier's gait, springy-kneed. Ancient art indicates this, as do skeletons, with decrease from prehistoric to modern times and about 20% incidence of cervical fossa of Allen (erosion of bone from stretched hip joint capsule). If bone markings at ankle (facets), shin (flattening), knee (tilt), femur shaft and neck, and perhaps lumbar vertebrae (wedging) are a complex, they fit this one explanation, though each varies individually and elsewhere may show different function!

Though microevolutionary change, describing a spiral fluctuation around a central trend over 5,000 years, definitely correlates with changes in population size and in diet and apparently with invasions, there is a point of inflection in Hellenistic times (shifts in skull length, metopic suture, and nose vs. mouth proportions) which is more easily explained by selection (family breakdown, infertility, infanticide, warfare, malaria?).

To use history as an experiment to handle such problems demands deeper physiological knowledge and more data for which a return to Greece is planned soon.

10. *On the antiquity of anatomically modern man.* S. L. Washburn, University of Chicago.

There have been two great theories concerning the antiquity of *Homo sapiens*. According to one, *Homo sapiens* existed all through the Ice Age while, according to the other, anatomically modern groups of men appeared during the time of the last glacial advance. The tide of discovery has turned heavily against the first theory and in favor of the second. The Piltdown and Galley Hill discoveries have been discredited. The Swanscombe and Fontéchevade fossils are too incomplete to prove either theory. At present there is no fossil which is both certainly *Homo sapiens* and certainly dated before the time of the last glacial advance. If this is true, the Mount Carmel and Kafzeh populations are, probably, ancestral to *Homo sapiens*, rather than hybrids.

11. *Relationships of the Australopithecinae, the great apes, and man as measured by coefficients of divergence for certain quantitative dental characters.* J. N. Spuhler, University of Michigan.

1. A coefficient of divergence for multiple characters is used to give a single measure of the divergence shown in certain dental measurements for 51 paired comparisons involving the Australopithecinae, the Great Apes, and two varieties of modern man — Australian and European.

2. The coefficients are smallest between the deciduous dentition of *Australopithecus africanus* and that of Australians. The divergence is increasingly greater in the order: Australian, Orang-utan, European, Gorilla, Chimpanzee.

3. The coefficient for the milk teeth of *Paranthropus* shows the smallest divergence from the Australian and increases in magnitude in the order: Australian, European, *Australopithecus africanus*, Orang-utan, Gorilla, Chimpanzee.

4. The adult dentition of *Paranthropus robustus* is most closely approximated by the Orang-utan and becomes more divergent in the order: Orang-utan, Gorilla, *Plesianthropus transvaalensis*, Australian, Chimpanzee, European.

5. The adult dentition of *Plesianthropus* is divergent from the other series measured in the order: Orang-utan, *Paranthropus robustus*, Gorilla, Australian, Chimpanzee, European.

6. Comparison of the mean coefficients of divergence shows a greater divergence within Great Apes (9 paired comparisons) than within the Australopithecinae (two comparisons) and the latter in turn are more divergent than within modern man (three comparisons).

7. When the data on the deciduous and permanent teeth are pooled the divergence between the Great Apes and Australopithecinae is 10.77 (on a scale from zero to 100), between Man and the Australopithecinae 10.87, and between Great Apes and Man 11.11.

12. *The Saldanha Skull from Hopefield, South Africa.* Ronald Singer, Anatomy Department, University of Cape Town, South Africa.

A general description of the site and of the morphology of the reconstructed cranial "cap," discovered by Mr. Keith Jolly and myself, is given. There is a striking resemblance between it and the Rhodesian Skull (Broken Hill Skull), and some features are in common with those from the *Sinanthropus-Pithecanthropus-Homo Soloensis* group, especially the latter. The Saldanha Skull is characterized by a moderately low brain case with its greatest breadth apparently near its base, a relatively narrow yet flat and receding forehead separated from massive supraorbital ridges by a distinct ophryonic groove. Its maximum length (glabella-opisthoecranion) is 200 mm, minimum frontal breadth 102 mm, and maximum breadth ? 144 mm. Other figures are also given. The skull is too incomplete for any dogmatic statement as regards its evolutionary status.

The fossil fauna (mainly mammalian) on the site suggest a late Pleistocene date, in terms of current African chronology. The stone implements indicate the presence of Man on the site from the late stage of the Chelles-Acheul (Stellenbosch) Culture (with which the Skull may be associated — Drennan, *Nature*, 172: 791, October 31, 1953) until the period when the Bush races were developing their culture.

13. *The evolution of the ilium.* Lois W. Mednick, University of Chicago Department of Anthropology.

The discovery of the pelvis of the South African man-apes offers the first direct evidence as to the course of actual change in the evolution of the pelvis. Although the ilia of these forms are similar to man's in general form, they differ in that the crest of the bone is less curved, lacks an iliac tubercle, and the gluteal surface of the bone is oriented in a single plane. The significance of these details for bipedal locomotion was investigated by the Benninghoff split-line technique.

In man, there is a thickened column of bone and a split-line tract running from the superior margin of the acetabulum to the iliac tubercle. This column is related to gluteus medius and gluteus minimus and its development is correlated with the functions of these muscles in bipedal locomotion as represented by man. The development of this column of bone and the split-line tract are absent in the Chimpanzee. In addition, the underdevelopment of these structures in the

Australopithecinae leads to the conclusion that these animals were less efficient bipeds than man. The ape-like characteristics of their ischia also substantiates this conclusion.

The whole pelvis is not the functional unit of evolutionary selection. The ilia of the South African forms show that the first change is the bending back and shortening of the ala of the ilium. The development of the iliac tubercle and the changes in the ischium are later.

DEMONSTRATION ABSTRACT

C. Split-line patterns in representative primates. Neil C. Tappen, Graduate School of Medicine, University of Pennsylvania, Philadelphia, Pa.

Split-line patterns in three anthropoid apes, two catarrhine monkeys, one platyrrhine monkey and one lemur are demonstrated with photographs and specimens.

DEMONSTRATIONS

A. Longitudinal studies of tooth formation from birth through puberty. Arthur B. Lewis and Dorothy Shoemaker, Fels Research Institute. (No abstract.)

B. The photovolt reflection colorimeter. Samuel Selby and Mary R. Crawford, Fels Research Institute. (For abstract see paper no. 22.)

C. Split-line patterns in representative primates. Neil C. Tappen, Graduate School of Medicine, University of Pennsylvania.

D. Instruments for research. Robert Butters, Yellow Springs Instrument Company. (No abstract.)

E. A biological approach to the constitutional components responsible for conformation and morphological variation. Paul B. Sawin and D. D. Clary, Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine. (For abstract see paper no. 39.)

F. Side trip to Wright-Patterson Air Force Base, Ohio. H. T. E. Hertzberg, Anthropology Section, Biophysics Branch, Aero Medical Laboratory.

REGULAR PROGRAM (continued)

14. Some features of abnormal growth in brains in mental deficiencies. James W. Papez, Laboratory for Biological Research, Columbus State Hospital, Ohio.

Cerebral cortex and hypophysis cerebri were examined under phase microscopes in 33 cases. In 20 cases, histological examination showed the following. (1) Cytoplasm of growing nerve cells was destroyed in early stages. Many areas of such dysgenesis appeared in sections of thalamus and cortex. Some nuclei of nerve cells were not destroyed, but remained without cytoplasm. They often lacked dendrites and axons, or functional connections. (2) In better developed brains more connections were present. Areas of thalamus and cortex showed agenesis and disturbed growth at advanced stages of cell development; with more cytoplasm, dendrites and axons. Cytoplasm was damaged by a degenerative process associated with inclusion bodies (organisms). Metabolic changes in nucleus were usual. (3) In severe cases of deficiency, cell masses in dorsal thalamus were disorganized and hard to recognize. They were factors limiting

receptive and cortical functions. (4) Early overgrowth of glia tissue around nerve cells in the gray matter, and of oligoglia tubing around axons and myelin in white matter was the prominent metabolic growth disturbance within the blood-brain barrier—with its functional implications. (5) Defective cortex showed dysgenic histology as itemized above. (6) Phase microscope preparations showed a heavy infestation of nerve cells in brain and hypophysis cerebri by special organisms. They may be the environmental factor. Foregoing 6 items were outstanding features of cerebral dysgenesis.

15. *An anthropological approach to the study of cephal-facial growth in the cleft palate child.* W. M. Krogman, Philadelphia Center for Research in Child Growth and Graduate School of Medicine, University of Pennsylvania, Philadelphia. (Read by title.)

16. *Growth patterns and rates in Southwest Indian populations: a comparative study of Apache, Pima, Papago, and White school children.* Bertram S. Kraus and James T. Barter, Department of Anthropology, University of Arizona.

A continuous record of heights and weights on 615 Tucson White, 260 White-river and San Carlos Apache, 174 Papago, and 252 Pima school children, ranging in age from 6 to 14 years, was recorded on Wetzel Grids. The data were secured from clinic cards maintained by the Indian Service Schools and the Tucson Public Schools in conjunction with the Indian Health Project sponsored by the Bureau of Indian Affairs and the University of Arizona.

Comparisons were made by ethnic group, age, and sex of channel distribution, number and amount of deviations from normal physique channel, developmental levels gained per year, age of greatest deviation from normal channel, average number of deviations from normal channel per growth period, and mean weights and heights.

In general terms, it was found that Pima and Papago growth patterns and rates differ significantly from either White or Apache. Pima and Papago children tend to veer toward the obese body build channels beginning in the circum-pubertal period and to reach terminal growth in channels to the left of their "normal" channels. Apache and White children tend toward the opposite direction but in less pronounced fashion. The growth of Pima children is more accelerated than that of the other groups, that of Apache is the least. Correlations were found between body build as expressed in the Wetzel Grid channels and certain constitutional disease frequencies. It is suggested that the Wetzel Grid should not be applied indiscriminately to non-white populations without further clinical knowledge of normalcy in such populations.

17. *The increasing body size in civilized man.* Edward E. Hunt, Forsyth Dental Infirmary, Boston.

Data from Davenport's monograph on the genetics of body build indicate that slender parents produced fewer adult progeny than did the parents of other physiques in white families living in the U. S. early in this century. Fleshy fathers, furthermore, produced a higher proportion of daughters. These con-

siderations suggest that the increased linearity of build of modern generations of civilized man may be occurring in spite of the breeding habits of their ancestors.

Bowles' study of trends of body size and proportions in parents and children, especially fathers and sons who attended Harvard, make many patterns of somatic change clear. The most pronounced elongations of the limbs occurred in the thigh and forearm. Along with some apparent elongation of the spinal column have come increases in thoracic kyphosis and lumbar lordosis.

Body composition has changed in the direction of less fat and more muscle in the sons, but probably less change in the volume of bones. The increased muscularity in the sons is meaningfully related to the changes observed in the thoracic and lumbar curves.

The elongation of the sons, especially in the thighs and forearms, and their increased muscularity, seem to be responses of tissues which tend to be greatly stimulated by environmental improvements during growth. The radius, ulna and femur grow chiefly from relatively active distal epiphyses, and muscle growth postnatally is greater than that of total body weight. These tissues may be disproportionately stunted in growth during adversity, and disproportionately enlarged under improved environmental conditions.

18. *Primate genetics as an approach to human genetics.* Neil C. Tappen, Graduate School of Medicine, University of Pennsylvania, Philadelphia.

Non-human primates offer possibilities for expanding the scope of human genetics tremendously. These possibilities are discussed. The disadvantages may not be so great as may have previously been supposed. Traditional problems of anthropology may be attacked with this new approach. Physical anthropologists would be appropriate investigators to enter this new field, increasing the areas regarded as being in the province of physical anthropology and adding to the social value of the discipline.

19. *Genetics, physiology and PTC.* Lucile E. Hoyme, Washington, D. C.

The bimodal distribution of thresholds of response to PTC supports the theory that high sensitivity to this substance is inherited as a Mendelian dominant. It has also been widely assumed that the expression of the genes does not vary with age, sex or environment. This latter assumption is not justified, for, like other gustatory responses tested by physiologists, the PTC thresholds of individuals have been found to vary from hour to hour. The apparent explanation is an alteration in the individual's physiological substrate.

Physiological factors can also affect the apparent proportion of "tasters" and "nontasters" in a population. The gene frequency of a population determines the relative areas of the two modes of the distribution; but the physiological substrate may shift all or part of the distribution toward higher or lower sensitivity. Thus, in a single population subdivided by age and sex, the peaks and valleys of the curves may fall at different places, with the areas of the respective segments remaining the same.

Testing a person or population once, or with a single concentration of PTC, is of limited value. To learn anything about the gene frequency of a population,

it is necessary to determine the distribution of thresholds, separating the modes at the concentration appropriate to the group. Gene frequencies obtained in any other way may have little relation to reality.

20. *A study of the hereditary blood factors among the Chippewa Indians of Minnesota.* G. Albin Matson, Elizabeth A. Koch, and Philip Levine, Minneapolis War Memorial Blood Bank, and Ortho Research Foundation, Raritan, New Jersey.

Studies of the genes for hereditary blood factors were carried out on three classes of Chippewa Indians (1) pure, (2) more than three-quarters pure, and (3) less than three-quarters pure. These high O Indians showed a dilution effect, corresponding to the degree of admixture with whites, in the frequency of genes O, A, and B, M, chromosomes R^2 , r (to a lesser degree also R^1) and genes Fy^a . Like other Indians studied recently, the Chippewa tribe is characterized by high M, high R^2 , low or absent r , and high Fy^a .

The contrasting frequency for the pure and least pure group is given for some genes or chromosomes studied:

	Pure	$\frac{3}{4}$
O	93.6	77.0
A	6.4	19.3
B	0.0	3.7
M	71.8	55.1
R^1	31.5	41.7
R^2	58.7	38.4
r	00.0	13.9
Fy^a	86.7	57.2
K	7.5	4.2

In general, these findings do not differ much from those reported by Chown and Lewis ('53) for the high A Blood Indians, but the pure Chippewas have a lower R^1 , higher R^2 , and no r in contrast to 2.7% r in the Blood tribe. Both tribes have chromosomes R^2 and r'' which are either absent or exceedingly rare in whites. The MN-Ss chromosomes differ in the two tribes, but this difference, mainly a higher value of Ns in the pure Chippewas (23.4 and 6.5%) may be associated with the higher M in the Blood tribe.

21. *An association between palm patterns and skin pigmentation within populations of hybrid origin.* David C. Rife, Institute of Genetics, Ohio State University.

An investigation of 100 northern Sudanese students at Khartoum, 100 Negro students at Ohio State University, and 167 Negro students at Central State College at Wilberforce, Ohio, revealed highly significant correlations between the shade of pigmentation and the incidence of patterns in the second interdigital area of the palm. The correlation was consistently high in each of the three populations, and in both males and females. No significant correlations were found between tasting ability and pigmentation, tasting ability and hand patterns, tasting ability and ABO blood groups, blood groups and pigmentation,

or blood groups and hand patterns. These data suggest linkage between genes responsible for skin pigmentation and patterns in the second interdigital area of the palm.

22. Photometric studies of skin reflectance in children, adults and pregnant women. Mary R. Crawford, Samuel Selby and Stanley M. Garn, Fels Research Institute for the Study of Human Development, Yellow Springs, Ohio.

Determinations of skin color were made in terms of the per cent of light in the blue end of the spectrum reflected by the exposed, unexposed and "sexual" skin. Skin reflectance was measured on 400 individuals from one month to 67 years of age using a photovolt model no. 610 reflection meter equipped with a blue filter with a transmission peak at 450 Å.

In the pubertal age range, the reflectance values for the "sexual" skin decreased in both sexes: areolar reflectance means changed from prepubertal values of 22.09% for males and 22.12% for females to 17.93 and 15.74% respectively. In the males scrotal reflectance evidenced a similar decrease averaging 16.18% prepubertally and 10.32 postpubertally.

Areolar reflectance means declined steadily from the third through the 9th month of pregnancy. All mean values during pregnancy were lower than those for comparable age groups of nulliparae and women measured 12 months post-partum.

Thus, in those areas called "sexual skin" there is evidence that hormonally mediated pigment changes are being measured. The findings also seem to indicate that the extent to which these areas respond to hormonal control is to some degree related to the capacity of the skin to produce pigment (tan) in response to actinic stimulation.

The assumption that these reflectance changes in the blue end of the spectrum are partly due to melanin is justified but further studies are now in progress to determine to what extent changes in melanin concentrations are responsible, rather than changes in superficial vascularity.

23. The racial affinities of the Baganda of British East Africa. Lawrence Oschinsky, The Philadelphia Center for Research in Child Growth.

Seligman, Johnston, and Leys and Joyce have expressed the view that the Baganda and certain other related Uganda Bantomorphs represent a mixture between a Congomorphie or Nigeromorphie racial type and the Bahima and Batutsi Hamitomorphs. They maintain furthermore that the Baganda in particular are in many features very similar to the Bahima and the Batutsi. Among these characteristics are thin lips, narrow noses, light coloured skins, tall stature and attenuated extremities.

The present investigation shows that this can no longer be maintained. The Baganda differ from the Batutsi in almost all the absolute and relative dimensions of the body. The Baganda are shorter in stature and have absolutely shorter sitting heights, trunk heights and total upper and lower extremities. The body indices of the Baganda indicate that they have relatively greater sitting heights

and trunk heights than the East African Hamitomorphs, but their total upper and lower extremities are relatively shorter than those of the above-mentioned group.

In regard to their absolute and relative head proportions, the Baganda have broader and shorter faces and much broader noses than the Bahima and the Batutsi.

The only marked similarity between the Baganda and the East African Hamitomorphs is their dolichocephaly and lip thickness. The Baganda and the Hamitomorphs are both equally thick-lipped, although the earlier authors ascribed thinner lips to the Hamitomorphs.

The data of Lehmann and Raper have shown for East Africa that there is an inverse relationship between the degree of Hamitomorphic admixture and the rate of sicklaemia. The Hamitomorphic Bahima have the lowest sicklaemia rate, the Nilohamitomorphs have a slightly higher rate, the Bantomorphs and the Nilotomorphs have still higher and very variable rates, and the Congomorphs Baamba have the highest rate. The anthropometric data of the author indicate a general trend between a low nasal index and a low sicklaemia rate amongst the Hamitomorphs and the opposite case amongst the Congomorphs. It is quite clear that the Baganda, as far as the author's somatometric data and the sicklaemia data of Lehmann and Raper are concerned, are the least affected by Hamitomorphic admixture among the 5 Uganda Bantomorph tribes studied in this report.

24. Racial characteristics of hair. Oliver H. Duggins and Mildred Trotter, Department of Anatomy, Washington University Medical School, St. Louis, Missouri.

Objective examinations of 5 characters of hair, form, color, index, area of cross section, and medullation, have been made on samples from representatives of the 4 primary races and of certain hybrid groups. The samples were taken from Eskimo, Paracus (mummy), Mexican Indian, Thai, Chinese, Beduin, Arab, French Canadian, American White, Australian Aboriginal, Southern Rhodesian, Cape "Colored," Bushman, British East African and American Negro groups.

The gross form of the hair, determined according to Martin's classification, ranged from ulotrich or kinky of the Negroid to lissotrich or straight of the Mongoloid. The Australoid most closely approximated the Caucasoid in this character. Hair color was determined with the Haarfarbentafel of Fischer and Saller, and the range of color, as expected, extended from black of the Negroid through blond of the Caucasoid. The smallest area and lowest index were exhibited by the Negroid; these characters were similar in the Caucasoid and Australoid which were intermediate between the Negroid and Mongoloid; and both were greater in the Mongoloid than in any of the other three races. The Mongoloid presented the highest incidence of medullation. In the hybrid groups the data were found to be intermediate between the races concerned. Thus, objective measurements reveal that hairs from different racial groups have distinguishing characteristics, despite a partial overlap.

25. *Polynesian craniology: preliminary formulations.* Donald Stanley Marshall, and Charles E. Snow, Peabody Museum of Salem, Salem, Massachusetts, and University of Kentucky, Lexington, Kentucky.

Polynesian craniology is discussed in the light of the author's preliminary analysis of over 1000 Polynesian crania. Particular attention is paid to environmental, socio-cultural and historical strictures, discussed in some detail. The survival factor involved in a reduction of population to a 10th of the original within a single generation, in some areas, is stressed. Basic problems, such as the eternal question of Easter Island, are pointed out. The data collated indicate that there was a morphologically and metrically distinct Polynesian type of crania, with such factors as the rocker jaw to be found throughout the entire area. Metrically the Polynesians appear most related to the Micronesians, but morphologically to the Melanesians. Subtypes within the area appear to be related to geographic, historic, and socio-cultural factors. There has been a marked change in crania through much of the Polynesian area since European contact, broadly correlated with the degree of transculturation. This makes the study of living so-called "pure blood" Polynesians dubious as a basis for drawing historical conclusions, but highly important for a study of the effects of race mixture, dietary change, and the like. Brachycephalization has increased throughout the entire area, although varying greatly in degree from one locality to another. This may be a manifestation of an unknown survival factor involved in post-European population decline.

Perhaps in Polynesia as nowhere else can the total interrelationship and interaction of environmental factors upon the relatively homogeneous population be demonstrated.

26. *Recent developments affecting the physical anthropology of the Jews.* Ailon Schulman, Middle East Institute, Dropsie College, Philadelphia, Pa.

This population has had a historical and anthropological development as the Hebrews, Israelites, and Jews. A new historical and anthropological development began with the establishment of the state of Israel in 1948.

The Israelis, in their incipient years, present a demographic picture of a youthful population, half of whom are recent immigrants. The population is quite fertile, with high age-specific birth rates, low age-specific death rates, and a high life expectancy rate (67.3 years for males and 71.7 years for females). The resultant net reproduction rate (1.75) is one of the highest in the world.

During their historical period as the Jews, this population became divided into Ashkenazim (generally those inhabiting Europe and the Western World), Sephardim (the Mediterranean countries), and Orientals (North Africa, southwest and central Asia).

Prior to 1948 this population emigrating to Palestine had been of an Ashkenazic nature predominantly—in way of life and physical type. However, since 1948 this trend has been reversed. Today the population is estimated as being 60% Ashkenazic and 40% Sephardic and Oriental. If present trends of natural increase and immigration continue, Israel will be, in another generation, a country predominantly Oriental.

27. *The question of physical selection of Mexican migrants to U.S.A.* Gabriel W. Lasker, Department of Anatomy, Wayne University Medical School. (No abstract.)

28. *Comparison of 55 middle aged former athletic champions with some 400 middle aged men and with normal young men.* Thomas K. Cureton, Physical Fitness Research Laboratory, University of Illinois, Urbana.

In comparison with the comparable normal adult sample of men measured on the same 128 tests the *former champions*, averaging 44.39 yrs., 69.37 ins. tall and 165.29 lbs. in weight were more mesomorphic (354), more linear in skeletal build and had less fat. The *former champions* also had slightly wider shoulders, smaller hips and smaller gluteal and abdominal girths; they also had better feet, stronger dynamometer strengths, and better cardiovascular tests (better Barach, Schneider and 5-Min. Step Test Scores, better Brachial Sphygmograms and higher T-waves in precordial leads IV and V).

The average weight residual of 17.05 lbs. was greater than that of the comparable sample of adults and even greater than the result for normal young men, indicating greater tissue density because these *former champions* were stronger and had less fat.

The lying and standing blood pressures were just average on the general adult tables, but the pulse rates were considerably lower. There was no indication that the *former champions* show relatively greater strain or deterioration but instead they had significantly stronger circulation, vagus tone and precordial ECG deflections.

In the ratio of the Area of the Brachial Pulse Wave/Area of the Frontal X-Ray (diastolic) the *former champions* showed greater proportionate stroke output per unit of heart size (3.489 compared to 2.599 for the comparable adult sample and 3.442 for young men). Their transverse heart diameters averaged 13.35 cm (+4.73%) compared to 14.12 cm for the comparable sample of adults and 13.1 cm for normal young men (+0.60%). Comparison of the groups on an All-Out Step Test for Time and Gross Oxygen Intake in the hard exercise showed the *former champions* to be superior to the comparable middle aged sample, but both of these older groups were poorer in Step-Test Time than the sample of young men. In gross oxygen intake the *former champions* were better than both other groups.

The *former champions* had strength per pound of body weight of 7.09 compared to 6.54 and 5.87 for the other two groups, respectively. The Vertical Jump Reaction Times were .271 secs. (visual), .254 (auditory) and .245 (combined) being about 5 Standard Scores above the adult average as were also the results for the Agility Run and Vertical Jump. However, both adult groups were considerably poorer in all-out chinning and dipping endurance exercises than the young men but here again the *former athletes* had deteriorated less than the comparable adult sample of men.

Division of the *former champions* into three sub-groups designated: (1) in continued training (2) moderately active and (3) sedentary showed statistically significant differences in favor of the group in training over the other two groups in practically all physical fitness test items.

29. *Studies of the effect of static loading on the lumbar intervertebral discs.* F. Gaynor Evans, Department of Anatomy, and H. R. Lissner, Department of Engineering Mechanics, Wayne University, Detroit, Michigan.

The influence of static and transverse (bending) loading on the intervertebral discs of the intact thoracic and lumbar spine has been studied in fresh (un-embalmed) and embalmed material from adult human males. The specimens were loaded to failure, as indicated by a falling off of the load, in a 5000-pound capacity Riehle testing machine calibrated to an accuracy of $\pm 1\%$. A special apparatus was made so the influence of bending of the spine in any plane could be investigated. The loads were applied at speeds of 0.050 and 0.071 inches/minute and the relationship of deflection to load for the specimen was plotted by an automatic stress-strain recorder attached to the testing machine. The strain produced in a vertebra during a test was recorded by an electric strain gage cemented to it. The effect of the tests upon the nuclei pulposi was determined by injecting the nucleus with potassium iodide and taking roentgenograms before and after testing. After testing the spines were sawed sagittally so the discs could be examined macroscopically. The influence of embalming upon the strength characteristics of the discs was studied by testing the ultimate compressive strength of embalmed and fresh discs. All spines and discs were moist when tested. Examples of the results thus far obtained are illustrated and discussed.

30. *Some contributions of Air Force anthropology to academic physical anthropology.* H. T. E. Hertzberg and Frank P. Saul, Aero Medical Laboratory; Irvin Emanuel, Antioch College.

Previous papers concerning Air Force anthropology have dealt mainly with the practical applications of standard anthropometric techniques and the development of new techniques. Many such applications are resulting in by-products of value to academic physical anthropology. Some of these by-products have emerged from the analysis of 132 measurements taken on more than 4,000 men. Studies completed or in progress include statistical summaries of measurements taken on both men and women; changes in bodily dimensions among both men and women during military training; the correlation of head and face measurements, of hand measurements, and both of certain body measurements; and a comparison of body build ratings made on the same sample by practitioners of both the Sheldon and Hooton system. In addition, biokinematic investigations of weights, volumes, and centers of gravity of body segments, and of muscular strength and mechanical advantage on representative samples of the American population are filling long-felt needs.

Research planned for the future includes an intensive study of bodily proportions, and the contouring of the head and face employing a new photographic technique.

31. *Regional distribution of body bulk.* W. T. Dempster, Department of Anatomy, University of Michigan.

A functional anthropometry oriented to problems involving different body positions cannot ignore the fact that body segments have mass. Such factors as balance, postural sagging, position preferences, and speed of movement are in

part reactions to the continual pull of gravitational forces on the several body parts, yet quantitative data are now limited to measurements on a few male cadavers. Techniques capable of giving good working data on test individuals or on representative builds are desired.

Forty young men, highly selected for physique, i.e., thin, rotund, muscular, and "median," were measured for cross-sectional area at 20 specified landmarks. Both area tracings and area-to-height plots, i.e., volume plots, were measured by planimeter. The total volume may be subdivided into segments by transverse or oblique lines corresponding with certain landmarks. These values, together with those based on water immersion of limb segments, permit the calculation of ratios of segment volume to body volume or body weight. Except for low values for rotund individuals, limb segment ratios are similar in all groups.

Volumes treated as mass, or corrected for densities based on cadaver segments, gave values for segment mass. On the basis of cadaver data on location of centers of gravity, locations of mass centers may be approximated.

32. Skin-fold interrelationships in young males. Russell W. Newman, QM Research and Development Center, Natick, Massachusetts.

Data on skin-fold thickness used in the calculation of body-fat has not measured on a single homogeneous sample of sufficient size to allow detailed comparisons of changes with increased obesity. The series reported here, consisting of approximately 1700 White and 300 Negroid males, permit such comparisons as well as indirect methods of assessing the applicability of calculating body-fat on Negroid males by use of relationships established on Whites.

The racial analyses clearly show a deficiency in subcutaneous fat in Negroids when compared to Whites of a similar age-group. The skin-fold site on the chest and arm appear most distinctive between these groups, but the Negroids are sufficiently similar to Whites in skin-fold relationships to warrant the use of a common formula for converting skin-folds to per cent body-fat.

Analyses of 5 skin-fold thicknesses on the body indicate that these areas do not show parallel or even linear changes in relation to increasing obesity. This phenomenon raises a question concerning the advisability of using a single linear multiple regression equation in calculating body-fat.

33. A minimum reading list in Physical Anthropology. Bernice A. Kaplan, Detroit, Michigan.

At the Wenner-Gren Summer Seminar in 1951 those attending began to devise a basic bibliography covering all aspects of physical anthropology. The intent was to list works in physical anthropology which any graduate student in anthropology could be expected to read. Thus, all anthropologists—wherever trained—could share this common core of knowledge, although those specializing in physical anthropology would certainly go beyond the basic bibliography. The annotated reading lists which were collected and which I edited at that time were not published as it seemed desirable to get a wider review of them. In the meantime there have been requests for these lists. If we now can have the

cooperation of the members of this Association, the minimum bibliography could be revised and issued soon.

The success of the project rests not only in the preparation of the reading lists, but in the assurance that these lists, once prepared, will be acceptable to physical anthropologists. Preparation of such lists, therefore, will be undertaken only if there is some assurance they will actually be used by teachers of physical anthropology. If your comments indicate approval we will make certain before publication that the items on the reading lists have had the thoughtful consideration of experts in the major branches of the field and are generally acceptable.

34. *The use of punch cards in physical anthropology.* Edmund Churchill (Anthropometric Project, Antioch College).

The functions of the sorter-counter, the tabulator (i.e., adding machine) with summary punch, the reproducer, the calculator, and the statistical machine are described. The use of these machines for coding data and for computing indices, correlation coefficients, and other statistics of interest to anthropologists is outlined. The circumstances in which punch card methods are most efficient are discussed; the ease of obtaining additional statistics (e.g., non-linear measures of correlation) once the basic statistics have been computed is stressed.

35. *A test of the anthroposcopic method.* Ruth V. Harper, Fels Research Institute.

While the validity of the anthroposcopic method has been a controversial subject for many years, few attempts have been made to correlate the visual appraisal of fat and muscle with objective data.

The purpose of initiating this study was first to test the degree of agreement between trained and untrained observers, in respect to their ability to judge apparent fat and muscle, on a rank order basis. Secondly, these rank orders were correlated with the rank orders of fat and muscle, as measured on soft tissue teleroentgenograms, and with other objective indications of muscle mass, such as creatinine excretion.

With an N of 62, the rank order correlation must be .22 or higher to be statistically significant. It was found that the inter-observer agreement between one trained and two untrained observers ranged from .78 to .85, in the rankings of apparent fat. The rankings of apparent muscle, determined by these same observers, had a lower correlation, ranging from .50 to .68. All three observers reached a correlation of .8 or higher with hip fat and trochanteric fat, as measured with vernier calipers on soft tissue x-rays, however, the correlations between apparent muscle and muscle, as determined on teleroentgenograms and by creatinine excretion, ranged from .03 to .4, with the majority of correlations falling below the level of significance.

From these results, it would appear that the anthroposcopic method is a valid indicator of fat, but that it has low predictive efficiency as a determinant of muscle.

36. *Social biology in a Cypriote village.* J. Lawrence Angel, The Daniel Baugh Institute of Anatomy of the Jefferson Medical College.

Despite challenging environment, disease (malaria, plague), tempestuous history (Greek, Phoenician, Assyrian, Persian, Ptolemaic, Roman, Moslem, Byzantine, Lusignan, Genoese-Venetian, Turkish, and British occupiers) and ethnic mixture (Cyprus villages are described by Buxton as keeping sharp local biological [and linguistic] differences since prehistoric times; perhaps through special social skills to maintain ethnic identity).

Testing this hypothesis in Episkopi, a well-irrigated south coast village of 600 Greeks and 700 Turks, including a Negro minority (ca. 50% being adults), a small male sample ($N=88$) shows some differences from north and central mountain Greek Cypriotes in measurements and in blood types, apparent continuity with first settlers (Neolithic), some similarity of each language and religious group with mainland Greeks and with Arabs respectively, and intra-village contrast between Greeks and Turks in physique (Greeks less linear) and in some genes (sex-linked recessive blindness among Greeks, polydactyly among Turks), though similarity occurs in blood types (ABO, MN, Rh), PTC tasting, peculiar caruncular hairs, etc., despite claims of separate descent even before Turkish invasion in 1571 (back to 8th century A.D. with Moslem-Byzantine compromise?). Variabilities are below normal in spite of Greek and Turkish accretions of 18-25% adults per generation evenly from neighboring coastal and mountain villages, impression of physical heterogeneity, and possible excess of homozygotes only in MN blood groups among Turks.

Though physically strong and quick-moving, villagers are apparently phlegmatic, laconic, and relaxed, with no overt tenseness between Greeks and Turks in separate sections of village (despite Turkish economic control), and equality for negroes and for Greek women. Tension shows only in fear of disease, in always unspoken wish to join Greece politically, and in overprotective but secretly scornful attitude toward blind men and families with "carrier" females. A second expression of the drive to control a tough, formerly malaria-ridden environment and to maintain freedom is the tender attitude toward children raised with complete permission to express aggressiveness and hence with early learning of adult role of inevitable hard physical labor and courteous self-control and hospitality.

37. *Varieties of sexual mating and human genetic systems.* S. Burt Aginsky, Department of Anthropology, City College, New York. (No abstract.)

38. *A preliminary study of estimation of weight of the skeleton.* Mildred Trotter, Department of Anatomy, Washington University.

Twenty-four White male skeletons from the Terry Collection have been studied in order to ascertain what measurements are most highly correlated with the weight of the skeleton. The mean weight of the skeletons is 4459.9 gm. They are considered to be dry and fat-free. They range in age from 18 to 87 years. The cadaver statures are known. The correlation coefficient between the weight of

the femurs and the weight of the skeletons is .9591. Because of this high correlation the femur was subjected to other measurements which could be made on the living. These measurements include length, area of a projection from an anterior view, and area of compact bone (as shown by x-ray) in the middle half of its length. Of these three, the compact bone area is the most highly correlated with skeleton weight, the correlation coefficient being .7634. The multiple correlation coefficient of the compact bone area and stature vs. skeleton weight is .8234 and the standard error of estimate, 475.5 gm.

Matiegka's formula for estimating skeleton weight from stature and maximal transverse diameters of the distal ends of arm, forearm, thigh and leg was tested by substituting cadaver stature and the transverse diameters of the appropriate bones for the measurements of the living. The correlation coefficient between the resultant estimated skeleton weights and the actual skeleton weights is .7007 — practically the same as was found between cadaver stature and skeleton weight.

39. *A biological approach to the constitutional components responsible for conformation and morphological variation.* Paul B. Sawin and D. D. Crary, Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine.

Recognized determiners of the inherent ultimate growth achievement of the mammalian individual are: (1) influences acting on general body growth; (2) those regionally localized; and (3) those mediated by the organs of internal secretion. Group 2 may be subdivided into (a) those affecting specific tissues and (b) those acting upon embryonic growth gradients or involving localized groups of organs or systems. Studies of the maturity indicators of the skeleton and of qualitative and quantitative vertebral characters of inbred races of rabbits has demonstrated existence of regional between-race differences in both axial and appendicular skeletons, which in crosses are transmitted generation in a predictable manner. Soft tissues also are involved and significant temporal differences can be noted. In two cases, dwarf (dw) and achondroplasia (da), specific genes are implicated. Recent study of embryonic stages shows that in two races the regional differences, manifested at birth and in the adult are apparent from the onset of ossification, perhaps earlier. This suggests that quantitative longitudinal observations (cross-sectional when necessary) made upon genetically uniform races, and their hybrid descendants, offer a valuable clue to differentiation of the fundamental biological processes involved in the development of the constitutional components of Sheldon. Success of the method seems limited only by the number of suitable landmarks which can be defined and methods of statistical analysis.

40. *The age incidence and familial nature of a bony bridge on the first cervical vertebra.* Samuel Selby, S. M. Garn, and Vera Kanareff, Fels Research Institute.

Previous workers (MacAllister, Allen, Ossenfort) have observed a tendency for the sulcus arteria vertebralis of C_1 to be "bridged" completely or incompletely by bony spicules. Such a tendency has been reported in up to 50% of dissecting room material.

Partial or complete bridging of the type described may be noted in lateral skull x-rays. Twenty-four per cent of 229 adults in the Fels Series exhibited some tendency toward bridging, as did 28% of 100 Fels children over 14. No significant sex difference appeared in the incidence of bridging, but the "complete" bridge was much more common in males. This trait may be noted as early as the second year, and is ordinarily present by puberty, if it is to appear.

Monozygotic twins show a high but not perfect degree of concordance for this trait. Siblings of affected children, and parents of affected children show a higher incidence (@ 50%) than in the Fels population as a whole. With both parents affected, nearly all of the offspring evidence bridging. The trait is definitely familial, appears to be hereditary, and Mendelian dominance is suggested.

41. *Scalp thickness and the fat-loss theory of balding.* Stanley M. Garn, Samuel Selby and Richard Young, Fels Research Institute.

Of the various explanations given for male pattern balding, the fat-loss theory is the only one not contradicted by evidence that male sex hormones play a major role in the etiology of "normal" balding. Kohl-Pineus, Schein, and more recently W. W. Young and Szasz and Robinson have built up an explanation for balding involving hormonally-mediated loss of scalp tissue in genetically susceptible males.

To test the fat-loss theory, we have measured the scalp thickness at bregma, using serial teleoroentgenograms, on over 500 individuals from 4 to 69 years of age. A matched-pair series of bald and non-bald men (all under 44) was set up as a further control.

It was found that scalp thickness at bregma increased in both sexes through the 5th decade, that the average scalp thickness is greater in males from age 10 on, and that no circum-pubertal male-limited decrease is observable either by cross-sectional or longitudinal analysis. Though markedly different in the amount of hairline recession (10 cm) the bald and the non-bald men were not significantly different in scalp thickness.

Why the adult male scalp is thicker despite his thinner subcutaneous fat elsewhere remains a problem.

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THE SECOND, OR ADULT, FEMALE MANDIBLE OF AUSTRALOPITHECUS PROMETHEUS

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ELEVEN FIGURES

Lamentable losses were suffered by South African paleontology in the deaths of Dr. Bernard Price on July 9, 1948, of Dr. Robert Broom on April 6, 1950, and of Professor C. J. van der Horst on October 10, 1951, which swept away in the short space of three years the founder of the Bernard Price Institute for Palaeontological Research, the member of the Board who had first fired the imagination of its founder, and finally the Chairman of the Board. These events had such a paralyzing effect upon the archaeological activities of the Institute after the 1949 season that excavation was not resumed until last year. Then the Wenner-Gren Foundation's generous gift of approximately £3000 made its continuance possible.

On April 15, 1953, excavation was resumed by Messrs. James Kitching and Revil Mason at the Cave of Hearths in the Makapansgat Valley. During July Mr. Alun R. Hughes, Senior Laboratory Assistant in the Department of Anatomy joined them to resume the program of sorting the Limeworks man-ape fossil dump he had initiated in 1948 and has carried on at about that time each year (except 1952). On July 29, 1953, he recovered the major portion of the undistorted, adult and probably female mandible, which forms the subject of this communication (see fig. 2). The last discoveries of outstanding importance had been those made in 1949.

The Institute had assisted Mr. Hughes financially in September and October 1948; during that year and the next he was helped by Mr. James Kitching and his brothers. In 1949 Mr.

Hughes was also accompanied by Messrs. R. Veitch and R. Vogts, in 1950 by Mr. Goldman, in 1951 by Dr. J. K. Grieves and in 1953 by Mr. H. N. F. Harington. Regular annual prosecution of dump-sorting has provided experience in field work for science students from the Anatomy Department and



Fig. 1 The present appearance (1953) of the sorting site on the hillside at the Makapansgat Limeworks dump showing the line of separation between the approximately 5000 tons of already sorted material to the right and the unsorted remainder to the left. One of the native laborers stands near the section in which all of the past discoveries of *Australopithecus prometheus* fragments have been made.

has accumulated an appreciable quantity of bone breccia. When discussing the predatory implemental technique of *Australopithecus* (Dart, '49) I indicated that the previous year's three to four months labor had resulted in the recovery of about 10 tons of breccia from approximately 600 tons of dump material. Since that time an additional quantity of well over 4000 tons of the dump had been displaced and a further

25 tons of breccia recovered. So at least 35 tons of breccia have been retrieved from approximately 5000 tons of limestone dump. As 10 tons of breccia yield about a ton of bone, the prospective bone yield from the accumulated labor is about $3\frac{1}{2}$ tons in weight of fossil bones (see fig. 1).

The amount of bone represented by this labor is significant because, despite persistent personal and press enquiry and field search during the past 7 years, no comparable deposit of broken bones has been reported from, or discovered in, the lairs of living hyaenas, leopards or indeed any carnivorous



Fig. 2 The adult female mandible of *Australopithecus prometheus* as it was found lying in the piece of limestone bone breccia. The fractured roots of the two left premolars and left canine teeth are plainly visible in the area broken by the blasting of the deposit.

beasts other than man elsewhere in Southern Africa. The australopithecine cave deposit at Makapansgat has unquestionably been made by carnivorous creatures; but its extent, as well as its nature demonstrate that the creatures had the



Fig. 3 The occlusal aspect of the adult female mandible of *Australopithecus prometheus*, circa natural size.

habits characteristic of mankind rather than those — as far as they are known — of living South African Carnivora.

Despite the wealth and variety of australopithecine remains found at the Sterkfontein, Kromdraai and Swartkrans sites in the Sterkfontein valley near Krugersdorp, accidents before death and earth movements subsequent to fossilization have usually led to fractures, or distortions of most of the mandibles



Fig. 4 Occlusal view (approximately $\frac{2}{3}$ natural size) of mandibles of the Taungs infant *Australopithecus africanus* (above) and the adolescent male *A. prometheus* (middle) and adult female *A. prometheus* (below) found at Makapansgat for comparison.

and losses in the tooth series, or dislocations of the teeth within the distorted jaws. This lower jaw from Makapansgat was also fractured before death a short distance behind the right third molar and it was fractured diagonally through the symphysis during the mining operations (see fig. 2). The recent fracture—from a superior point behind the left second premolar to an inferior point below the right second

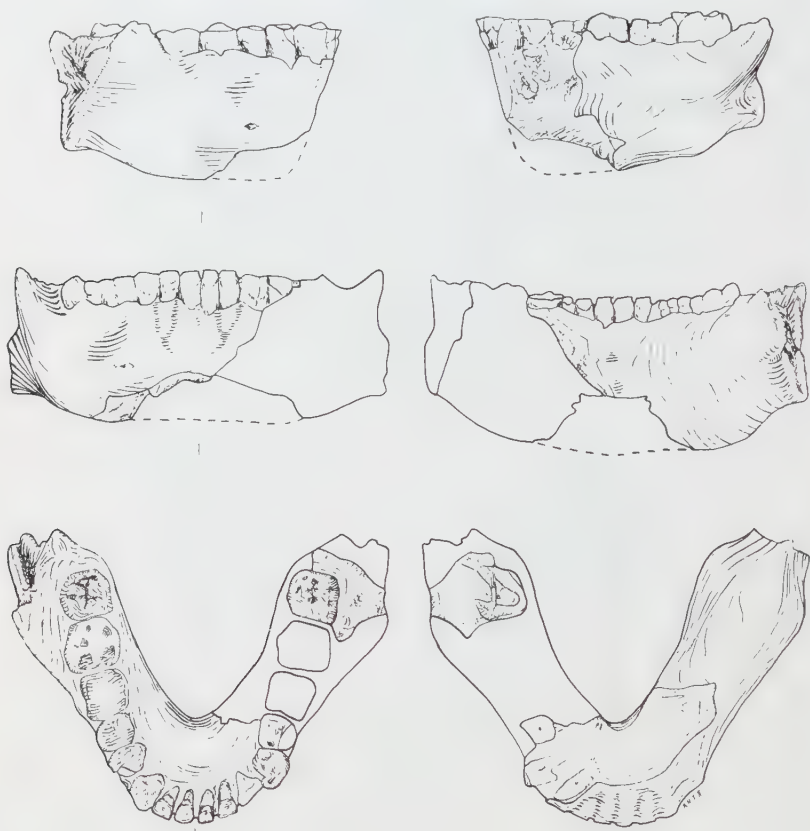


Fig. 5 Adult female mandible of *Australopithecus prometheus* as seen from the lateral, medial, anterior, posterior, superior and inferior aspects respectively, including the third left lower molar previously described (Dart, '49, fig. 5) $\frac{1}{2}$ natural size.

molar — has, however, left the alveolar region relatively intact, and the dental series is preserved undistorted and virtually complete from the second left premolar to the third right molar inclusive (see fig. 3).

AGE OF SPECIMEN

A broken isolated third left lower molar was recovered 5 years ago and described along with the cranio-facial fragment (Dart '49; fig. 5). That third left molar resembles the third right lower molar of this mandible in size, wear and colour so closely that there is no doubt about its belonging to this mandible, so that only the left first and second molars are missing, and the bone and the dental series was probably complete from third molar to third molar before the blasting. The remainder of the jaw and the two missing teeth may yet be recovered (see figs. 4 and 5).

When describing that isolated left third molar I suggested that it came from the lower jaw of an adult female of the same age as the cranio-facial fragment. No third upper molar was present in that fragment but the size (14×14) of the left third lower molar seemed consonant with that of the first and second upper molar teeth then being described. To avoid assuming the presence of an excess of individuals I suggested that the left lower third molar had probably come from the same individual. The recovery of this mandible, however, shows that the attrition of its premolar and molar teeth is considerably more advanced than in those of the cranio-facial fragment. The lower jaw belonging to the cranio-facial fragment is therefore still missing and this lower jaw must have belonged to another adult female somewhat more advanced in age.

DESCRIPTION OF SPECIMEN

(To avoid repetition of the letters "mm," all integers used are measurements given in millimeters unless otherwise stated.)

Text figure 5 exhibits the mandibular fragment from its several aspects when oriented on the alveolar and sagittal

planes and a coronal plane at right angles thereto. The clean, jagged plane of fracture through the premolar and canine roots anteriorly show its recent character; the slight erosion of the bony margin of the posterior fracture found embedded in the limestone shows that it was broken before fossilization; the marginal crushing in that region may indicate some of the violence to which its possessor was subjected immediately before or after death.

The anatomy of infantile, adolescent and adult australopithecine mandibles is so well-known from the previous publications of Dart ('25, '29, '34), Broom and Schepers ('46), Dart ('48), and Broom and Robinson ('52) that it is adequate here merely to summarize such features as seem relevant to place this fragment on record and to indicate how it expands our knowledge of the group to which it belongs.

The external aspect (see fig. 5). In its general morphology, as was shown for the adolescent male mandible (Dart '49), the lower jaw of *A. prometheus* resembles more closely that of *H. heidelbergensis* and *Sinanthropus* than that of living anthropoids or recent men; this adult female specimen corroborates that conclusion. The australopithecine, as compared with the anthropoid, mandible characteristically has a very robust and shortened body, associated with a relatively narrow and high ascending ramus. The robust body (compare also figs. 6 and 11) is essential to accomodate the relatively large premolars and molars of grinding type in the Australopithecinae. In *A. prometheus* these features are associated, as in *Sinanthropus*, with a *prominentia lateralis* on the lateral aspect of the ramus-body juncture and a *torus lateralis superior* continuing from the antero-lateral aspect of the ramus onto the body of the mandible. The torus lateralis superior in *A. prometheus* becomes continuous in the symphyseal region with the alveolar jugum surrounding the first premolar and canine on each side postero-superiorly and with its fellow of the opposite side by means of a transverse symphyseal ridge across the somewhat retreating and presumably chinless symphyseal region antero-inferiorly. The premolar-

canine alveolar jugum on each side is continuous inferiorly with its fellow of the opposite side through the same transverse symphyseal ridge. With it there also fuses the inferior widening of the vertically-running common median alveolar jugum embracing the central incisor teeth. This median alveolar jugal widening meets inferiorly the premolar-canine jugum on each side in such a way as to form a U-shaped lateral incisor fossa external to the lower part of the lateral incisor root. The slight widening out and swelling inferiorly of the central incisor alveolar jugum also gives rise to a typical *trigonum mentale* in the "chin" region homologous with the *tuber symphyseos* of Weidenreich in *Sinanthropus* (compare Broom and Robinson, '52, p. 24 and fig. 22).

A single mental foramen lies 18 (*Paranthropus* females 17-20; *Telanthropus* 14) below the second premolar. Below the mental foramen and the upper part of the torus lateralis superior in which it is lodged, there is a horizontally-running *sulcus interoralis* separating the superior torus from the inferior or *marginal torus*, as in *Sinanthropus*; but of these anatomical features only the posterior portion is visible owing to the fracture. At the posterior end of the fractured lower border of the mandible enough bone is present to show the relatively abrupt, keel-like reduction of the body thickness in cross-section behind the third molar to form the ramus, whose inferior border was kinked downwards and slightly everted relatively to the body as in both *Paranthropus* and *Sinanthropus*. The fossa or *sulcus extramolaris* between the last two molar teeth and the ascending ramus peters out anteriorly; and what we may term a *torus lateralis suprema* replaces it to link the anterior margin of the mandibular ramus to the alveolus laterally to the first molar in such a way as also effectively to separate the *sulcus extramolaris* from the *lateral mandibular depression*. This latter broad depressed area lies on the lateral aspect of the mandible between the premolars above, the torus mandibularis below, the thickened ramus-body junction surmounted by the prom-

inentia lateralis posteriorly, and the broad canino-premolar alveolar jugal thickening anteriorly.

This supreme lateral torus separating the sulcus extramolaris from the lateral mandibular depression is a human feature. The presence of the ridge separating the two depressions distinguishes this mandible from those of living anthropoids where there is little or no indication of the *torus lateralis suprema*, and consequently the broad groove of the *sulcus extramolaris* forms a gutter that continues uninterruptedly into the scalloped lateral aspect of the anthropoid mandible.

In *Paranthropus crassidens* also the sulcus extramolaris peters out between the anterior margin of the ramus and the bony junction between the first and second molars as in man; but the lateral mandibular depression found in *A. prometheus* is replaced in *Paranthropus* by a diffusely elevated and featureless thickening of the whole lateral aspect of the body extending from the lateral aspect of the ramus behind to the fossa of the lateral incisor in front.

The thickness, 20.5, of this adult female mandible in the vicinity of the first permanent molar is practically the same as that of the adolescent *A. prometheus* 21; but its height, 34, is a centimeter greater than in the adolescent 24. The thickness-height measurements of the adult female *A. prometheus*, 20.5×34 , are virtually the same as in the Heidelberg mandible 20×34 , and show nearly half a centimeter less thickness but exactly the same height as the male *P. robustus* 24×34 . The *P. crassidens* measurements are somewhat variable but their mandibles are generally thicker and higher (type adolescent 24.2×35.7 ; complete adult female 24.5×37.0 right, 24.1×35.1 left; adult male 20.0×39.8 right). The thickness in the vicinity of the third molar of the huge male *P. crassidens* jaw reached the astounding figure of 35.6; i.e. greater than the height at the first molar of this female specimen, of Heidelberg, of the male *P. robustus*, and even of some *P. crassidens* males. These dimensions show incidentally the wide range in variation in australopithecine mandibles.

The most conspicuous characteristic of the lateral aspect of the female *A. prometheus* mandible, however, apart from what we may term its Heidelbergian robusticity, is its brevity. As the anterior margin of the ramus sweeps up behind the second and not the third molar, the distance between the anterior borders of the symphysis and the remus in profile is no greater than that found in the female *Sinanthropus*; and considerably less than that in the male *Sinanthropus* (see figs. 8, 9 and 11); and the Middle Stone Age Boskop Man found at Tuinplaats on the Springbok Flats (Broom, '29) in the Central Transvaal (see fig. 10).

The internal aspect (see fig. 5). The contrast between a slender ramus with a 2-4 thickness and a robust body with a 25-35 thickness causes some large male australopithecine mandibles to assume an appearance which in comparison with a living human or anthropoid jaw is almost grotesque. The contrast in thickness is most conspicuous when the bone is seen from its internal, inferior and posterior aspects. In consequence, with respect to robusticity, australopithecine lower jaws contrast vividly with those of living anthropoids. Thus an adult male gorilla mandible in the department, having a symphyseo-ramal mandibular length of 185, has a 21.5 body width opposite the third molar. The adult female *Paranthropus* with a corresponding length of only 115, i.e. roughly *only two-thirds that of the gorilla*, has a 28.0 body width, or *is nearly a quarter again as robust as the gorilla's mandible*. As their second molars are of practically comparable width (*Gorilla* 15.6, *Paranthropus* 14.8) these architectural divergences between the mandibles of these two higher primate types are obviously the result of the different kinds of work that their teeth, especially their molars, are called upon to perform and not due to divergent molar tooth size. In point of fact, although australopithecine lower jaws are more robust, their molars are actually smaller than those of the gorilla.

Just as the juncture of the body and ramus of the australopithecine mandible exhibits externally the thickened body and *prominentia lateralis*, so it features internally anterior

to the mandibular foramen a salient *torus triangularis*, the fusion of the three crests: *crista endocondyloidea*, *crista endocoronoidea* and *crista pharyngea*. The torus and the two former crests are not present in this specimen owing to the absence of the ramus but its moderately salient *crista pharyngea* is continued into a robust *prominentia alveolaris* owing to the great thickness of the alveolar part of the body. As *A. prometheus* has a well-modelled body, not being diffusely thickened, its alveolar (thickness 27) and subalveolar (thickness 17) halves are distinct from one another and separable by a mylo-hyoid line bounding the *fossa subalveolaris* above.

The *torus triangularis* in *Paranthropus* is just as prominent a feature of the internal aspect as in living anthropoids; it is even more sharply defined owing to the thickened body and strong *crista pharyngea*; but the distance between the toral point, where the three crests meet, and the third molar in the male gorilla is 42 while in the female *Paranthropus* it is only 25. Despite their correspondence in molar size the rotational mechanics of australopithecine lower jaws have resulted, even in the massive-jawed *Paranthropus*, in its having been slung posteriorly between the condyles in such a fashion as to diminish by approximately a half — as compared with *Gorilla* — the distance between the posterior margin of their non-locking molar teeth and the coronal intercondylar plane, on which they are hinged and at a right angle to which they rotate horizontally. Doubtless it is the necessity for such lateral rotation that had decreased that length.

The loss of the lower third of the symphysis in *A. prometheus* precludes us from knowing whether, as seems probable, there was present a second or inferior (transverse) mandibular torus. Such a torus was not present in the adolescent male *A. prometheus* mandible, but is present in the adult female *Paranthropus*, and in the female *Sinanthropus* and Heidelberg mandibles. The probability that such an inferior torus was present in *A. prometheus* is increased by the existence of a *torus marginalis* externally and of a definite

genio-glossal depression with a nutrient foramen at its foot internally.

In figure 6a the sagittal contour of the reconstructed symphysis of *A. prometheus* (heavy uninterrupted line) in median section has been superimposed upon those of *Paranthropus crassidens* (interrupted line), *Homo heidelbergensis* (dotted line) and the adult female *Sinanthropus pekinensis*. In figure



Figure 6 A



Figure 6 B

Fig. 6a The symphyseal contour (lower portion restored) in the median sagittal plane and oriented on the alveolar plane of the lower jaw of the adult female *Australopithecus prometheus* (heavy uninterrupted line) superimposed upon the corresponding contours of the adult female *Paranthropus crassidens* (interrupted line); *Homo heidelbergensis* (dotted line); and the adult female *Sinanthropus pekinensis* (light uninterrupted line), natural size.

Fig. 6b Symphyseal contour of *Australopithecus prometheus* as in figure 6a superimposed upon the corresponding contours of the orang ♀ (dotted line), chimpanzee ♂ (interrupted line) and gorilla ♀ (light uninterrupted line) employed by Weidenreich ('35, fig. 71). Natural size.

6b its contour is superimposed on those of the Orang ♀ (dotted line) Chimpanzee ♂ (interrupted line) and Gorilla ♀ (light uninterrupted line) employed by P. Weidenreich ('36, fig. 71) for comparison with *Sinanthropus*. The anterior surfaces of the two australopithecine mandibles are shown by these comparative super-impositions to be more nearly vertical, i.e. more hominid than those of Mauer or Peking. The height and thickness of the australopithecine symphyses are considerably greater than those dimensions in the other two hominids; but

the general pattern at the symphysis is similar throughout the hominid series and is thus hominid rather than pongid in the Australopithecinae. It is suggestive too that, if the lower part of the promethean contour has been correctly restored, its features of symphyseal height and thickness are approximately intermediate between those of *P. crassidens* on the one side and those of Mauer and Peking on the other.

Above the genioglossal depression is the broad convexity of the inner mandibular arch (*arcus intermedius* of Virchow), which forms the main transverse linkage between the two alveolar prominences of the mandible. The *arcus intermedius* limits posteriorly the upward-facing and transversely-lying concavity of the *planum alveolare*, whose excellent state of preservation in conjunction with a virtually complete series of teeth lends to this mandible its peculiar value.

The occlusal aspect (see figs. 3, 4, 5, 7 and 11). As might have been inferred from the study of text figure 5 the most salient morphological features of the occlusal aspect prove to be the form, sizes and arrangement of the incisor and canine teeth relative to the premolars and molars; and the influence they exercise on mandibular architecture especially in that portion lying anterior to the coronal plane passing through the anterior margin of the first molar ("post-lacteon").

Through the kindness of Mr. J. T. Robinson I have been enabled to examine a recently-discovered, and as yet undescribed *Plesianthropus* mandible whose anterior portion is also complete; and to compare the region in question with that of *A. prometheus* and of *P. crassidens* (see fig. 7, and compare Broom and Robinson, '52, fig. 18). The general form and size of the incisors and canines relative to the premolars and molars in *A. prometheus* resemble more closely those seen in *Plesianthropus* than those in *Paranthropus*, because the premolars and molars are relatively so massive and the incisors and canines so small in *Paranthropus*.

Because of the comparable smallness of their incisors and canines the bicanine width in *Paranthropus* (34) is scarcely greater than that in *Plesianthropus* (33) and actually less than

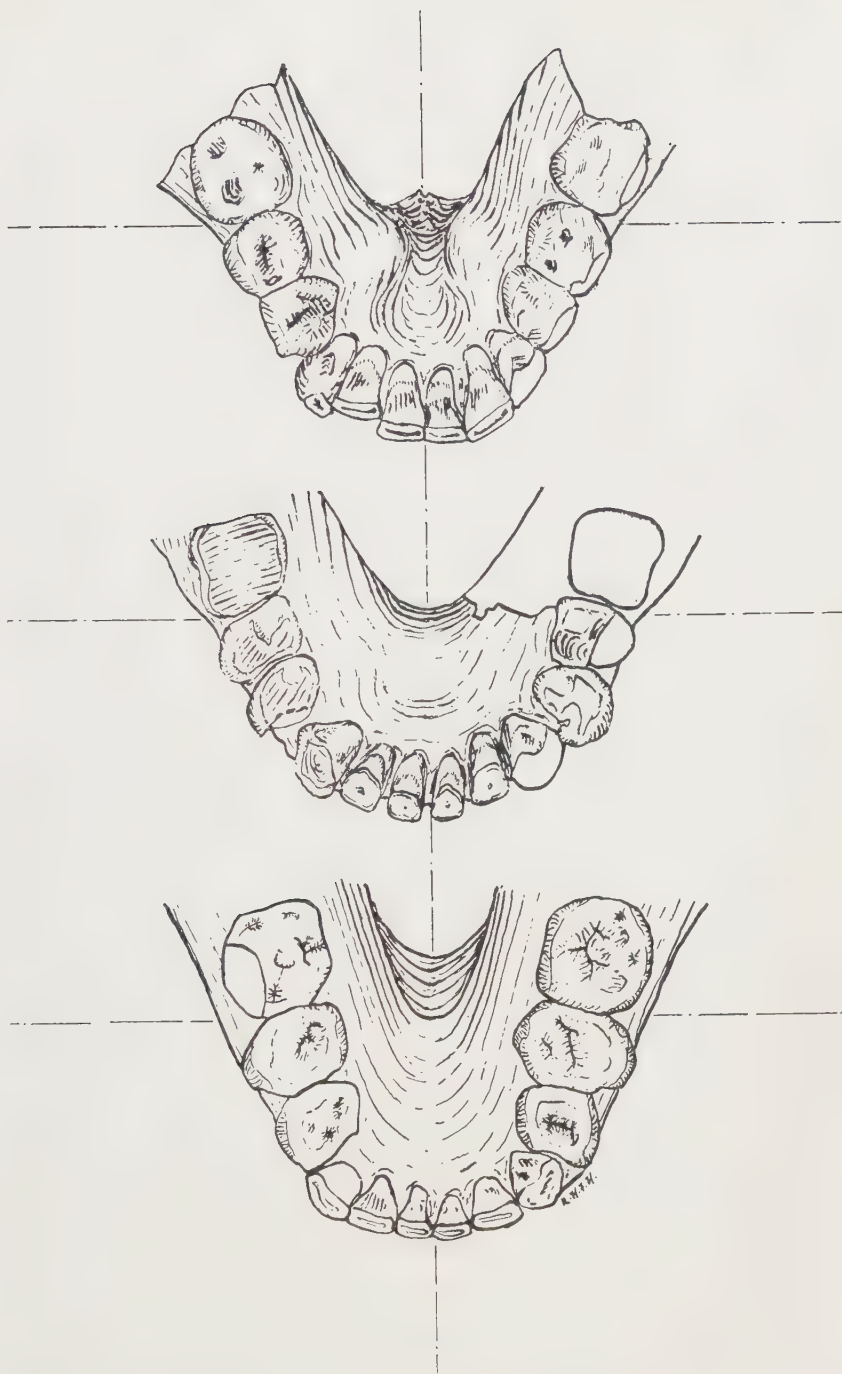


Fig. 7 Occlusal aspects of the *pre-lacteonic* portions of the mandibles of:—*Plesianthropus transvaalensis* (above); *Australopithecus prometheus* (middle); *Paranthropus crassidens* (below) to show the variation in the size and arrangement of the teeth and in the form of the dental arcades and alveolar fossae. Natural size.

that in *A. prometheus* 36, which is the same as in *H. heidelbergensis* and one less than in the male *Sinanthropus* 37. Despite these general similarities in the form and size of the australopithecine incisors and canines their arrangement differs. In *A. prometheus* the incisors and canines are all well-formed teeth set vertically in the jaw. Their edges being in comfortable contact with those of their neighbours, these teeth are neither crimped, crowded nor procumbent (see also figs. 3 and 4). The well-spaced and well-proportioned incisors and canines of *A. prometheus* contrast with those of *P. crassidens* (Broom and Robinson, '52, p. 79) where, although set vertically and not procumbent, "these anterior teeth appear disproportionately small in comparison with the premolars associated with them. They occupy a very small portion of the alveolar arch and in the case of the perfect mandible there appears to be insufficient space to allow of normal placement." In the *Plesianthropus* mandible the anterior teeth, despite the relative smallness of the premolars and molars, are even more crowded than those of *Paranthropus* and both the incisors and the canines are procumbent (see fig. 7).

The canines are situated postero-laterally to the lateral incisors and these in turn postero-laterally to the central incisors in all three australopithecines, but in *A. prometheus* the first and second premolars also participate in this postero-lateral displacement to a far greater extent than in *Paranthropus* and *Plesianthropus*; and consequently *A. prometheus* approximates most closely the human arrangement. As there are no diastemata between the canines and the lateral incisors mesially or the first premolars distally, and as the molar rows diverge, and as the third molars are reduced in *A. prometheus*, the entire dental series forms an evenly-curved parabolic arcade of a form as human as that seen in Peking man (see fig. 11).

Correlated with these dental peculiarities is the divergent morphology of the *planum alveolare* in the three australopithecine types, which for descriptive purposes can be defined

as that part of the mandible, bounded anteriorly and laterally by the premolars, canines and incisors and posteriorly by the coronal plane passing through "post-lacteon" (anterior margin of first molar).

The length of the alveolar plane can be taken in the mid-line from the post-lacteon coronal plane to the posterior alveolar margin of the central incisors and its width as the minimal width between the lingual borders of the second premolars. In terms of these measurements the alveolar plane in *A. prometheus* is short 17 and broad 32 simulating in measurement the male *Sinanthropus* 14×33 though in the latter it falls away from the incisors more steeply. In the female *Paranthropus*, according to Broom and Robinson's ('52) reconstruction, it is long 23 and narrow 22. It is also more deeply grooved from side to side, or scooped out in *Paranthropus* and in such a way that the elongated *alveolar fossa* so formed runs antero-posteriorly whereas the broad concavity of the alveolar fossa in *A. prometheus* lies well-forward and forms a rather shallow, transversely-running depression between the two first premolars.

The alveolar plane, or better still its fossa, appears even more elongated and more scoop-like in *Paranthropus* because its massive inferior mandibular torus juts posteriorly and because the body of the mandible itself as well as its premolars and molars are so huge. The external bi-premolar width (at the second premolar) however, is identical 51 in both *Paranthropus* and *Plesianthropus* whereas in *A. prometheus* it is 54 and (as fig. 11 shows) virtually equivalent with that of *Sinanthropus* 55. The width of the alveolar plane between the relatively smaller premolars of *A. prometheus* is thus correspondingly increased for an australopithecine.

While resembling *A. prometheus* more than *Paranthropus* in relative tooth size, *Plesianthropus* presents an alveolar fossa that is so deep and contracted behind and comparatively expanded in front that it can best be described as salt-spoon-shaped. Despite the relative smallness of the premolars the measurements of the alveolar plane 18×28 show that they

are no more divergent than those of *Paranthropus*, and, as if to replace the massive premolars and generally thickened body of *Paranthropus*, the *Plesianthropus* mandible has developed on the lingual aspect of each side prominent tuberculated swellings. These medial swellings of the alveolar prominences in the premolar vicinity form a *torus mandibularis* (see fig. 7) on each side analogous to that found by Weidenreich (op. cit p. 52 et seq.) in *Sinanthropus*, Mongolian and other human, as well as occasionally in chimpanzee and gorilla mandibles.

The salt-spoon-shaped appearance of the alveolar fossa in *Plesianthropus* is emphasized by its narrowing into a gutter posteriorly between these medial mandibular elevations and the prolongation of its concavity anteriorly and laterally by the general scoop-like arrangement of the compressed and procumbent incisors and canines.

Whether the structural variations displayed by these three mandibles will prove to be consistent divergent characteristics of these three Australopithecinae can only be known when adequate comparative material is available. It might be argued that their classificatory significance may not be great since comparable mandibular and dental diversity could be discovered amongst the mandibles of *Homo sapiens*. They are depicted, however, in case any or all of these features should assist, along with other morphological details of the dentition and other parts of the skeleton, in demonstrating specific divergence between the three types they represent today. Meantime the anterior part of the mandible and its dental arcade in *A. prometheus* are shown thereby not only to resemble more closely those of other primitive hominids than do those of *Plesianthropus* or *Paranthropus*; but also to approximate more closely the unspecialized or intermediate type of jaw apparatus from which the other two comparable, yet divergent types of scoop-like mechanisms (both possibly specialized for gnawing as opposed to grinding) in *Plesianthropus* and *Paranthropus* have been derived.

The most informative single comparative measurement from the occlusal aspect is the chord from the medial margin of the central incisor to the mid-point on the posterior margin of the third molar, which in *A. prometheus* is 72 and in the male *Sinanthropus* 75. In the female *Paranthropus* this measurement is 82 (compare Broom and Robinson '52, p. 20) i.e. a centimeter greater; and in the male chimpanzee 99 and gorilla 110 (as illustrated by Broom and Schepers, '36, p. 131), i.e. nearly 3 and 4 cm greater respectively.

The attrition of the *A. prometheus* teeth is advanced, but the 5-cuspal pattern of the third molar previously described (vide Bart, '49) is still apparent and the almost vertically-placed incisors still retain a 3-5 depth of their buccal enamel. Hence their state of wear does not affect the significance of the preceding total tooth series comparison between *Sinanthropus* and *A. prometheus*. The equivalence of these two dental series is all the more remarkable if we recall firstly that the robusticity of the incisor-canine-premolar series in the upper and of the whole of the lower dentition in *Sinanthropus* exceeds that of the average Australian aboriginal and the robusticity of the upper molar series in *Sinanthropus* is definitely less than that of the average Australian aboriginal; and if we remember secondly, that all the known *Sinanthropus* molars both upper and lower, are well within the size-range of Australian aboriginal molars (vide Weidenreich, '37).

The maximum measurements of *Sinanthropus* and Australian aboriginal lower molars may be compared with those teeth in this mandible thus:

SINANTHROPUS		AUSTRALIAN		A. PROMETHEUS
M 1 \times 14.1 \times 12.8	<	14.0 \times 13.5	>	12.0 \times 12.8
M 2 \times 13.2 \times 12.7	<	14.25 \times 13.5	<	14.0 \times 14.6
M 3 \times 12.9 \times 12.4	<	14.0 \times 13.0	<	13.8 \times 13.8

From this short list it is apparent firstly that the first molar in this female *A. prometheus* falls well *within* the range of both Australian and Peking man; and secondly that, while the

second and third molars in length and breadth are both outside the range of Peking molars, they are both *within the length range* of Australian molars and exceed the known breadth range of Australian molars by no more than 1.1 and .8 respectively. Thirdly the list shows that *the process of relative reduction in size of the third molar*, hitherto supposed to be characteristic only of man, has already occurred in *A. prometheus*, the ascending order in size being M1 — M3 — M2, precisely as occurs in the Australian aboriginal and also in *Telanthropus*.

The close human affinities indicated by these size relationships of the teeth are corroborated by the attritional plane of wear of the *A. prometheus* canines. The plane of wear in the canines coincides on both sides with that of the incisors mesially and the premolars distally. This horizontal occlusal plane of attrition demonstrates once again and in conclusive fashion that in the adult, as in the infantile *Australopithecus*, the attritional movements were horizontal and grinding as in man (Dart, '25, '29, '34) and not vertical and cutting as in living apes. The lower canine teeth themselves (right 8.0×10.3) are not quite as robust as some male *Sinanthropus* lower canines (no. 17, 9.0×10.4 ; no. 72, 9.0×10.1) but are definitely broader than female *Sinanthropus* lower canines (nos. 69 and 73, 8.1×8.2 ; no. 18, 8.5×8.7).

Detailed description of the dentition of this specimen, however, is reserved for a later communication, in which it will be possible to discuss individually both the lower and upper teeth of *A. prometheus* in the light of the previous discoveries and a series of developing permanent teeth (lateral incisor to second premolar inclusive) recently recovered from an infantile maxilla that had also been discovered previously. Meanwhile Le Gros Clark ('52) and Robinson ('52, '53) have discussed the essentially human character of the australopithecine dentition as a whole; and the first permanent lower premolar in the adolescent mandible of *A. prometheus* has formed the subject of a specially exhaustive study by Remeane ('52).

DISCUSSION

With the aid of the occipital, cranio-facial and adolescent mandibular fragments, we had made in 1949 a provisional cranial facial reconstruction of the *A. prometheus* female, now generally available to museums through the American Institute of Human Paleontology and the Anthropology Museum of the University of Pennsylvania. This new mandible and dentition being so nearly complete, it was relatively simple to reconstruct it pictorially with the assistance of the previous reconstruction, and so to facilitate comparison with those of other types. A reversed image superimposed on the contour of this specimen gave an accurate outline of the other half of the body and dentition. The previous reconstruction indicated the maximum ramal height; and meantime the complete *Paranthropus crassidens* female mandible (Broom and Robinson, '52), the original of which was also kindly loaned by Mr. Robinson, served as a further guide to the probable width and general form of the missing parts of the rami.

Reconstructing this *A. prometheus* mandible, while using for orientation the alveolar margins as the horizontal plane and a perpendicular plane dropped from it at post-lactean (i.e. the premolar-molar contact) as the coronal plane, the checks mentioned showed

(a) that the posterior borders of its condyles were probably 4 anterior to those of our previous *A. prometheus* female reconstruction and 8 in front of those in Weidenreich's *Sinanthropus* male reconstruction.

(b) that the posterior border of its ramus was probably a little more nearly vertical than in the previous reconstruction

(c) that in our previous reconstruction the contours of the mandibular notch, coronoid process, anterior border of the ramus and inferior border of the mandible all required such slight adjustment as was necessary to conform to

- (i) the 4 decrease in length (45 in the adult female as compared with the 49 adolescent male) of the visible part of the alveolar border in norma lateralis.
- (ii) the 4 increase in height (34 in the female, 30 in the adolescent male) of the mandibular body.

From these reconstructions and comparisons it follows (see text figs. 7, 8, 9, 10 and 11) that this promethean mandible is not only smaller than any hitherto described adult australopithecine mandible, but is also smaller in many respects than

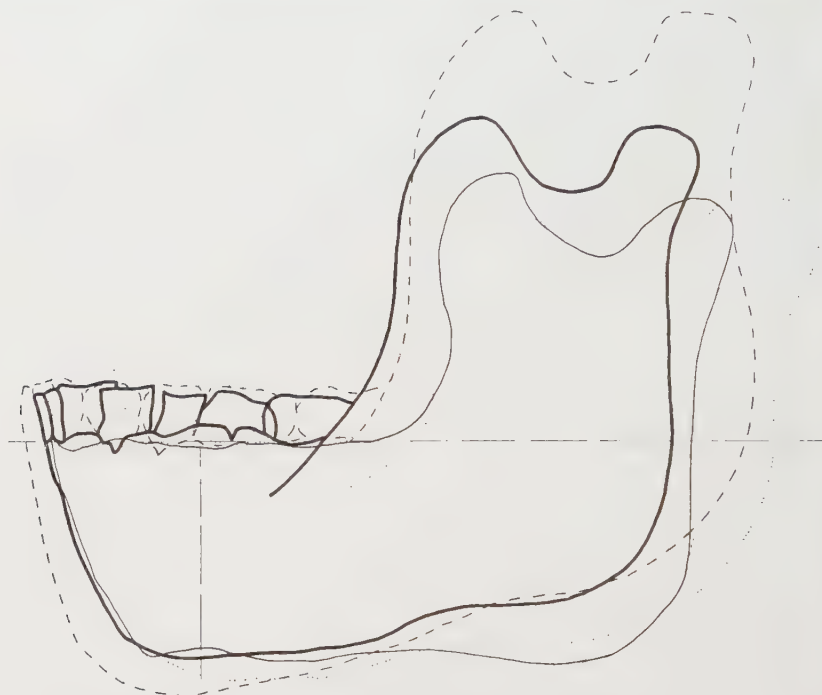


Fig. 8 Superimposition of contours in norma lateralis and on the alveolar and lacteonic planes of the mandibles of *Australopithecus prometheus* (heavy continuous line) and *Paranthropus crassidens* (discontinuous line) on those of *Sinanthropus* (light continuous line) and *H. heidelbergensis* (dotted line). Note the identity between *A. prometheus*, *Sinanthropus* and *H. heidelbergensis* in growth of the pre-lacteonic portion of the mandible and the excessive growth of *Sinanthropus* and *H. heidelbergensis* in the post-lacteonic part.

various fossil human jaws such as those of Heidelberg and Peking Man and even the Springbok Flats Middle Stone Age Boskop skull from Tuinplaats (Broom, '29, Schepers, '41) in the Transvaal.

I have already discussed the morphological intermediacy of *A. prometheus* between *Plesianthropus* and *Paranthropus*.

Text figures 8 and 9 have been prepared for the purpose of comparing in norma lateralis the contours of what we may term the two extreme adult female australopithecine forms *P. crassidens* (interrupted line) and *A. prometheus* (heavy continuous line) with the two most divergent known primitive human forms *Sinanthropus* (light continuous line) and *H. heidelbergensis* (dotted line). In text figure 9 the 4 mandibles have been superimposed on a perpendicular to the alveolar plane through the point called "post-lacteon" by Bolk ('26), i.e. the anterior margin of M 1 (see Weidenreich, '36, p. 99); in text figure 9 the anterior borders of the rami have been superimposed as they cross the alveolar plane.

The first obvious fact emerging from both of these superimpositions is that the adult female mandible of *Paranthropus* represents an overall enlargement of the same type of lower jaw as is found in the female *Australopithecus*. The reasonable deduction is that the mandible of *P. crassidens* presents a gerontomorphic variation of the more generalized type exhibited by *A. prometheus*.

Unfortunately for the purpose of fabricating derivatives, Bolk introduced the clumsy hyphenated term "post-lacteon." To avoid the paradoxical derivative term "pre-post-lacteon arch" necessitated thereby for that portion of the mandible lying in front of this point Weidenreich (loc. cit.) substituted the term "anterior alveolar arch." He was then able to apply the term "alveolar arch" to the complete arch, but this strategy failed to deal with the nomenclature of the "post-post-lacteon" parts of the jaws and their portion of the dentitions.

It would be serviceable to rename as "lacteon" the point originally called by Bolk "post-lacteon." Whether this advice be followed or not I see no difficulty in applying here the terms "lacteon" and "post-lacteon" to those parts of the jaws lying respectively anterior and posterior to a coronal plane through the anterior margin of M 1, whether it be named "post-lacteon" or more briefly and perhaps more wisely "lacteon."

When describing the adolescent *A. prometheus* mandible ('48) I could only compare it with that of Taungs and those of the adults of *Plesianthropus* and *Paranthropus robustus* illustrated by Broom and Schepers ('46). Weidenreich (op. cit.) had previously demonstrated how, in *Sinanthropus*, the process of widening the jaws during ontogeny causes this anterior or *lacteonic* part of the human mandible to be shortened; whereas in anthropoids, whose jaws do not widen as greatly, it is lengthened during the growth that takes place subsequent to the eruption of the milk dentition.

Now we are able to compare the infant Taungs mandible and the adolescent male Makapansgat mandible with the adult female *A. prometheus* mandible (see fig. 4) and with the contour superimpositions now under discussion. This comparison necessitates an important modification of my previous conclusion based on the *Plesianthropus* and *Paranthropus* adult comparison. I then (op. cit. p. 401) wrote "The comparative growth series of mandibles now available reveals a remarkable stage of intermediacy between anthropoids and man in respect of forward facial growth during australopithecine ontogeny." That conclusion of australopithecine intermediacy may still be true as far as *Plesianthropus* and *Paranthropus* are concerned. This new comparative series of australopithecine mandibles does not exhibit intermediacy between anthropoids and man on the part of *A. prometheus*, however, but rather *identity* with *Sinanthropus pekinensis* and *Homo heidelbergensis* in respect of forward facial growth during ontogeny.

Equally remarkable is the fact that, despite this identity, when oriented on this lacteonic coronal plane in norma lateralis, the post-lacteonic growth of the *A. prometheus* mandible is seen to be exceeded not only by *P. crassidens* but also by *Sinanthropus* and *H. heidelbergensis*. Further it is patent that in respect to post-lacteonic growth *Homo heidelbergensis* exceeds not only the male *Sinanthropus* but also the female *P. crassidens* as well.

These two admittedly human though primitive and divergent types have mandibular rami which are not quite so elevated as that of *A. prometheus*; but there is less difference in height of ramus between the two primitive human beings and *A.*



Fig. 9 Superimposition of the same mandibular contours as are seen in figure 8 but superimposed at the point where the anterior margins of the rami cross the alveolar plane instead of lacteon.

This superimposition facilitates comparison of the ramus and body in *Australopithecus prometheus* with the corresponding parts of the mandible in its australopithecine relative from South Africa and the other two primitive hominids from western Europe and eastern Asia respectively.

prometheus than there is between the two female Australopithecinae in that feature. Nor is there as great divergence between *A. prometheus* and the two human beings in height of ramus as there is between *A. prometheus* or *Sinanthropus* on the one side and *H. heidelbergensis* on the other in post-lacteonic growth.

Further, a basis of morphological separation cannot be found in the width of the ramus; because, when the anterior margins of the rami are superimposed (see fig. 9) where they cross the alveolar plane, it is evident that the width of the

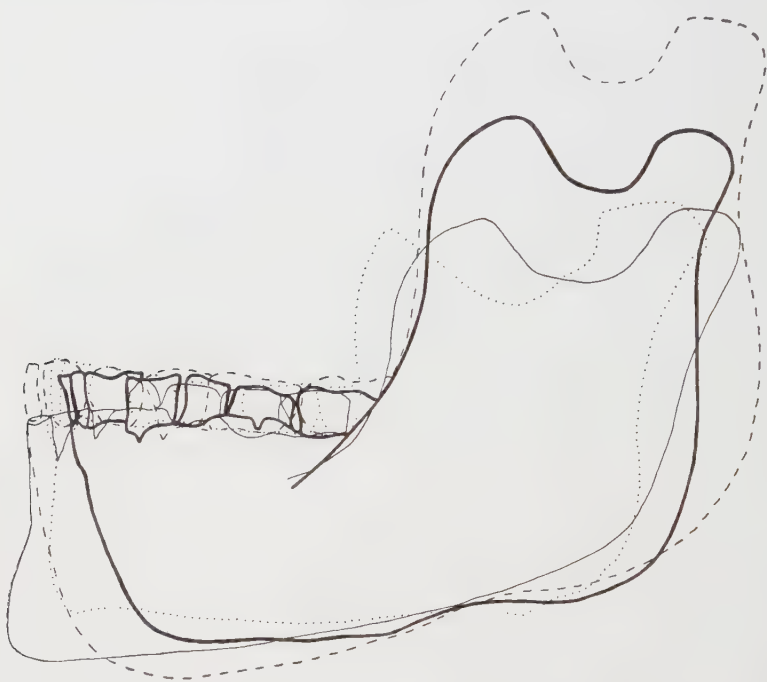


Fig. 10 Superimposition in norma lateralis of the contours of two australopithecine mandibles, viz. *Australopithecus prometheus* (heavy continuous line) and *Paranthropus crassidens* (interrupted line) upon those of two Boskop mandibles, viz., the Middle Stone Age specimen from Springbok Flats (light continuous line) and the recent pre-Zimbabwe specimen K 3a from Bambadyanalo Hill at the Mapungubwe site on the Limpopo river (dotted line). Both of the human mandibles are from the Transvaal.

ramus in *A. prometheus* is intermediate between those of *Sinanthropus* and *H. heidelbergensis*. In other words the degree of divergence between the two primitive human rami is greater than that between either of them and *A. prometheus*. The body height is greater in *Sinanthropus* and *H. heidelbergensis* than in *A. prometheus*.

Lest it be imagined that the only types of human jaw, with which australopithecine jaws can tolerate comparison, are those of very primitive human beings from the remotest parts of the Old World Land mass, text figure 10 has been prepared in which the contours of the two australopithecine mandibles have been superimposed upon two South African human mandibles from the Transvaal.

One of these is the mandible of the Springbok Flats skull (Broom, '29) a fossilized Middle Stone Age individual of



Fig. 11 Superimposition of mandibular contours from the occlusal aspect of *Australopithecus prometheus* (heavy continuous line), *Sinanthropus* (light continuous line), and *Homo heidelbergensis* (dotted line) on the posterior margins of the third lower molars to illustrate the divergences in robusticity and length of the three mandibles; the comparability of the dental arcades in *A. prometheus* and *Sinanthropus*; and the "Gothic" divergence in form which the arcades in these two types exhibit as compared with the "Roman" form of dental arcade in *Homo heidelbergensis*.

Boskop type unearthed from calcareous tufa 3-4 feet below the surface about 70 miles to the south of Makapansgat (vide Gates, '48). The Boskop mandible represented by the Springbok Flats (light uninterrupted line) individual is the largest human mandible discovered in South Africa, having a total length greater even than that of the Mauer jaw (Schepers, '41). Its ramus is as broad as, or even broader than, that of *A. prometheus*, but the dentition is microdont and there is a well-marked projecting chin in consequence of the reduction in the dental arcade. Despite these advanced features in its morphology this Boskop mandible from Springbok Flats has approximately the same body height as *A. prometheus*; and while not so robust owing to its microdont condition, has a considerably greater total and physiological length.

The other Transvaal mandible (dotted line) is a recent Hottentot individual (ref. no. K. 3a) and obviously of the same Boskop type but was unearthed from the pre-Zimbabwe culture strata on Bambadyanalo Hill at the Mapungubwe site on the Limpopo River. Its symphyseal contour is intermediate in form between that of Springbok Flats and those of the Australopithecinae; but its ramal width is as great as that of the Springbok Flats specimen, and so is greater than that of *A. prometheus*, with which it also vies in body weight.

Finally text figure 11 is a superimposition of the contours of the *A. prometheus* (heavy continuous line) lower jaw from the occlusal aspect upon those of *Sinanthropus* and *H. heidelbergensis* (dotted line). For this comparison the plane of the posterior margins of the third permanent molars has been utilized instead of that through the anterior margin of the first permanent molar or "lacteon."

The divergence between *A. prometheus* and the two primitive human mandibles is seen to be fundamentally in the shortness and stoutness or robusticity of the australopithecine jaw. The Mauer jaw, while longer than both of the others, is intermediate between *Sinanthropus* and *A. prometheus* in stoutness. The contours of the mandibular arch and the microdont dental arcade in *H. heidelbergensis* in norma ver-

ticalis approximate those of the Roman, rather than the Gothic form found in these two arches in both *Sinanthropus* and *A. prometheus*. Obviously the dental arcade of *Sinanthropus* is closer to that of *A. prometheus* than it is to that of *H. heidelbergensis*; and although the mandibular arch of *A. prometheus* is the more pointed of the two, the dental arcade of *Sinanthropus* is actually somewhat sharper than that of *A. prometheus*.

The teeth of *H. heidelbergensis* are notably smaller than those of both *Sinanthropus* and *A. prometheus*; so it is obvious that there are as great or greater differences of size between the teeth of *Sinanthropus* and *H. heidelbergensis* than there are between those of *Sinanthropus* and *A. prometheus*. The dental arcades of *Sinanthropus* and *A. prometheus*, correspond virtually tooth for tooth.

It should be recalled that a female adult *A. prometheus* is being compared with a male adult *Sinanthropus*, the sex of the Heidelberg individual being unknown. There is an appreciable sexual divergence in the jaws and teeth of *Sinanthropus*; the range in sexual divergence in *A. prometheus* may have been greater in *A. prometheus* than in *Sinanthropus* and certainly appears to be greater in other australopithecine types, such as *P. crassidens*. Whatever that australopithecine sexual-variational range may have been the basic fact remains that there are greater morphological divergences between different known types of human jaws and teeth than there are between the female *A. prometheus* and the male *Sinanthropus*.

The promethean mandible preserves in its symphysis and ramus of moderate height and width and its body of reduced length and height an intermediate form between, on the one hand, the massive mandible of *Paranthropus* with its anteriorly and posteriorly elongated and thickened body and elevated and widened symphysis and ramus, and on the other hand the lower and narrower symphyses, the more slender and heightened but posteriorly elongated bodies and low broad rami of these primitive types of East Asiatic, West European

and South African human beings. Such an intermediate mandibular form with its concomitantly reduced prognathism presumably characterized the common ancestral source from which these more extreme australopithecine and human mandibular variations diverged.

Some of the features in which the dentition of *A. prometheus* approximates and transgresses the range of variation in sinanthropine and living human teeth have been discussed in the body of this article. The proximity in relationship between the promethean and certain human dentitions (e.g. *Sinanthropus* and Australian aboriginal) contrasts with the divergences therefrom displayed by living microdont human types on the one side and by plesianthropine, and paranthropine, australopithecine types on the other. Such an intermediate type of dentition also presumably characterized the common ancestral source from which these more extreme australopithecine and human dental variations diverged.

The study of the australopithecine dentition and more especially of the premolars of the adolescent *A. prometheus* led Remane ('52 p. 308) to conclude "dass das Gebiss der Australopithecinae eine Reihe echt hominider Charaktere zeigt, aber auch eine Reihe von Merkmalen, in denen sie zwischen Hominiden und Anthropoiden stehen (Form der Eckzähne z. B., untere Molaren). Durch die vorgeschrittene Molarisierung der Prämolaren und der vorderen Milchmolaren weichen sie sowohl vom Anthropoiden und allen primitiven Primaten ab."

The series of genuine hominid characters shown by the adult female *A. prometheus* lower jaw and teeth display even more emphatically the difficulty of determining the mandibular and dental boundaries, between the Australopithecinae and other early Hominidae, if indeed such boundaries existed.

In conclusion I wish to express my grateful thanks to Mr. J. T. Robinson for the courtesies mentioned above and to my assistants: to Mr. Alun R. Hughes for the thoughtful photographs, to Mr. H. N. F. Harington for the careful line drawings and diagrams that illustrate this paper, to Mrs. H.

Erikson for her accurate preparation of plaster casts, to Mrs. B. E. Wilson for her patient preparation of the typescript, and to all those who have participated in the work at Makapansgat during the past nine years.

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CATALOGUE DES HOMMES FOSSILES. Edited by Henri V. Vallois and Hallam L. Movius, Jr. *Comptes rendus de la XIX^e Session du Congrès Géologique International*. 378 pages. Algiers, 1952. 500 francs.—This catalogue has recently appeared and become available for distribution. It may be obtained from: Secrétaire General, XIX Congrès Géologique International, Faculté des Sciences, Alger (Algerie), French North Africa. It comprises a systematic listing of all human fossils, giving notes on discovery, nature of deposit, accompanying materials of all kinds, bibliography, and present resting place or fate of the original specimen. It is excellently and carefully arranged, and its extraordinary value to physical anthropologists hardly needs pointing out. It is supposedly obtainable only at the source given above, but any trouble in sending for it should be outweighed by the modest price.

THE SALDANHA SKULL FROM HOPEFIELD, SOUTH AFRICA¹

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TEN FIGURES

INTRODUCTION

The site. During the past 25 years a number of fossilized animal skeletal remains had been submitted by farmers and District Surgeons of the south-western coastal area of the Cape Province to the Cape Town Museum and the above department, but no scientist had subsequently investigated those sites. In May, 1951, I was instrumental in locating an extensive fossil site on the farm "Elandsfontein" about 10 miles from Hopefield, which is a small village situated 90 miles north of Cape Town and about 15 miles east of Saldanha Bay³ (figure 1). Here, in the middle of the sandy veld, situated 300 feet above sea level, is a veritable Solutrean-like accumulation of fossilized material lying on the floors of wind-scoured kloofs or depressions between stationary vegetated or moving sand-dunes. Ridges of ferricrete cut diagonally across the length of the site, and, in places, the dunes are capped by massive calcrete mounds or flat boulders of partly silicified surface lime-

¹ A modified form of this paper was read on behalf of the author by Dr. W. L. Straus, Jr., at the 23rd Annual Meeting of the American Association of Physical Anthropologists, Yellow Springs, Ohio, on March 27, 1954.

² I wish to acknowledge the kind permission of Professor M. R. Drennan, head of the Anatomy Department and Director of the Hopefield Research Committee, to present this paper. Mr. Goosen, Department of Surgical Research, kindly photographed the skull for me.

³ Saldanha Bay was named after Antonio de Saldanha, captain in Albuquerque's fleet which visited South Africa in 1503. "Saldanha" is a Portuguese name, correctly pronounced "Saldanya," but common local usage interprets it as "Saldarn-a."

stone. Softer, cellular calcretes are found in certain places at the lowest parts of the depressions. The tortuous courses of the ferrierete ridges indicate that they are the indurated lower flanks of old sand-dunes now stripped bare of the sand walls (Mabbutt, personal communication). This ferruginisation is

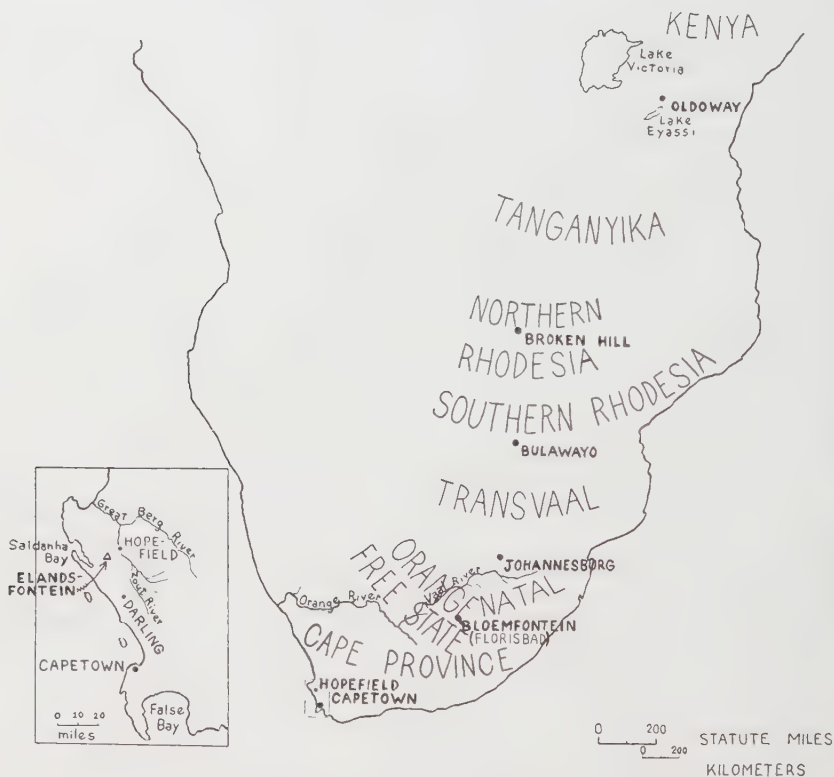


Fig. 1 Map of South Africa, showing sites described.

usually associated with moist ground conditions, a fairly high and stable water-table and an abundance of vegetable acids in the soil. It seems that this fossil site may at one time have been a large vlei or lagoon continuous or contiguous with one of the mouths of the large rivers that open into the sea 12 miles away. The site at "Elandsfontein" which extends over an area of approximately two square miles is not an isolated one, as I

have already explored two similar fossil-bearing locations, one on each side of this farm, lying in series with it parallel to the coastline. It may yet be shown that all these sites are segments of one massive geographical fossil area.

On numerous subsequent visits, various members of the University of Cape Town staff, Doctors M. R. Drennan, J. A. Keen (later replaced by E. N. Keen), Messrs. J. A. Mabbutt and K. Jolly, and I have collected highly fossilized bones and stone implements from the surface of the site.

Stone implements. The rich collection of stone implements indicate the presence of Man on the site from the period of a late stage of the Chelles-Acheul (Stellenbosch V) Culture until the period when the Bush races were developing their culture. This occupation was certainly not a continuous one. The most striking elements of the archaeological collection are the tool types of the Chelles-Acheul, namely, hand-axes (large and pygmy), cleavers, unconventional cutting tools, pebble choppers and bola-like stones. In addition, there are examples of the Middle Stone Age Still Bay Culture, but it is not mixed with implements of the Howieson's Poort Development, which is a more developed stage. Furthermore, some unique specimens of worked bone tools have been recovered by us (*Illustrated London News*, September 26, 1953, page 480, fig. 1). Drennan ('53a, b) stated that the Saldanha skull (described below) belonged to the "palaeoanthropic Man who practised the last stages of the hand-axe culture in South Africa." There is, however, no stratigraphical or direct proof of this yet.

Fossil fauna. The large amount of palaeontological material collected thus far is in the early stages of identification and general description by Dr. E. N. Keen and myself. Already established is a good series of suid teeth which is diagnosed as being almost identical to *Mesochœrus olduvaiensis* Leakey (except in size) and we have a detailed description awaiting publication. There is an impressive collection of the teeth of various species of horse, among which are many specimens of the extinct *Equus capensis* and allied types. Our classification of the equid dentitions would indicate a wider variability

within a species than has hitherto been accepted in this country, and will probably allow the merging of several described species. The 8 giraffid teeth thus far discovered appear to be indistinguishable from the extinct *Sivatherium* (from the Siwalik Hills, India) and also resemble the extinct South African *Griquatherium*. There are numerous teeth and long bones of *Palaeoloxodon*, both the black and white rhinoceros, and *Hippopotamus amphibius*. A large variety of *Bovidae*, extinct and existing, have also been identified by us (to be published in the Indian Journal of Palaeontology). Especially important are complete dentitions, skulls, horn cores and long bones of a long-horned buffalo, *Bubalus* or *Homoioceras*, definitely different from those few specimens previously described from Southern Africa. Generally speaking, in this fossil collection of existing and extinct mammals, the proportions indicate an Upper Pleistocene period, probably from the later part of the Middle Pleistocene onwards, in terms of current African chronology (which is based mainly on the beds at Oldoway in Tanganyika and the Vaal River beds in South Africa). True stratification has not yet been found at Elandsfontein, and it is debatable whether the same mode of dating is to be applied at a site 2000 miles away. Consequently, it has not been decided whether the profusion of extinct species at this one site may suggest an early part of the Upper Pleistocene. Such factors as the tropical climate at Oldoway and the temperate coastal climate at Cape Town will have to be taken into account in making these decisions. Fluorine tests, carried out through the courtesy of Dr. Oakley of the British Museum on a wide range of specimens, do not support the idea that specimens of a widely differing age have been mingled in the collection. Dr. Leakey recently informed us that none of the *Mesozoer* specimens in East Africa have been recovered from Upper Pleistocene deposits, but that his specimens were found in Middle Pleistocene layers, namely, Beds I and II at Oldoway. Thus if one tends to be conservative about the dating at Elandsfontein, the presence of *Mesozoer olduvaiensis* represents the survival of an isolated species which had become

extinct further north. However, our *Meschoerus* teeth are slightly longer, narrower and higher-crowned than the mean of the few recorded specimens of *M. olduvaiensis* Leakey. Thus if our specimens prove to be definitely beyond the range of variation of *M. olduvaiensis* Leakey, then these differences in dental development can best be interpreted as later stages and suggestive of our specimens being offshoots of *M. olduvaiensis*. Fluorine tests also revealed that the *Meschoerus* and *Paleo-*loxodon** lived contemporaneously with Saldanha Man at Elandsfontein.

THE SALDANHA SKULL

On the first field trip after my return from the U.S.A. on January 8, 1953, Keith Jolly, a young archaeologist, then employed as a field research assistant at Hopefield, and I discovered and identified 11 fragments of human fossilized cranial bones on the main site. They were lying loose on the sandy surface over an area of about 16 square feet, some with the endocranial surface uppermost and some with the exocranial surface uppermost. One fragment was later discarded as it was not human. The fragment 1 A (fig. 5) which drew our attention to the others was part of a right frontal bone with a massive supraorbital torus (extending almost to the median line) from which a marked temporal ridge extended back to bifurcate almost immediately into two less distinct temporal lines. Posteriorly this fragment tapered to a narrow base of about 1 inch, the border of which was the edge of the coronal suture in the region of the pars pterica. On the endocranial aspect part of the orbital roof was present while the orbital plate had an irregular broken edge, and a portion of the frontal sinus extended into the plate. Another key fragment consisted of most of the occipital squama in the lambdoid suture region, thus providing the posterior occipital curve and opisthocranion (coincident with inion here). Fortunately the remaining fragments (numbered 1.B. through 1.J. on the endocranial part of the reconstruction) had distinct landmarks, and, by making full use of sutural markings, most of the vault in the region of

the major sutures could be juxtaposed, and it was possible to reconstruct accurately the maximal height and length of the skull.

On two subsequent visits in January and February, Jolly and I retrieved additional fragments within a radius of 10 yards of the initial site of the discovery which, when added to the reconstruction completed most of the frontal bone. These fragments were classified 2.A., 3.A. (these two not being found

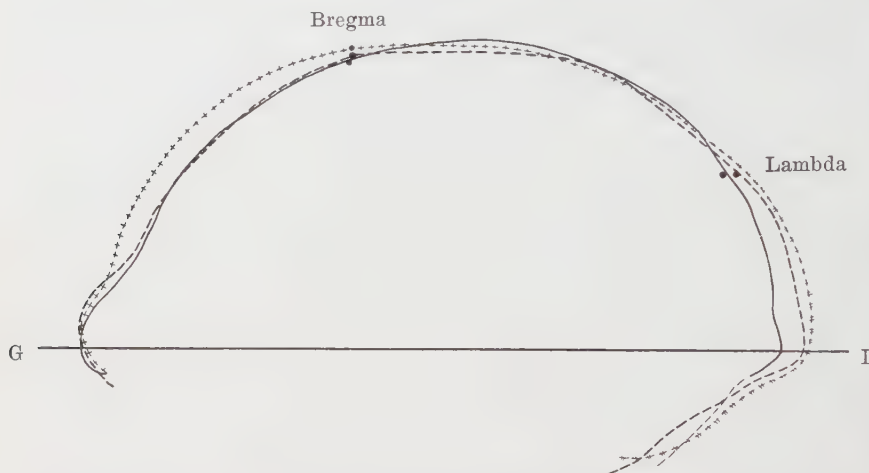


Fig. 2 Sagittal dioptographs, orientated in glabella-inion plane, using glabella (G) as fixed point, indicate relationships between Saldanha Skull ———; Rhodesian Skull — — —; and Florisbad Skull + + +. (### indicates plaster reconstruction in Florisbad Skull; — — — indicates plaster reconstruction in Saldanha Skull.)

at the original site—vide infra) and 16 fragments were marked "3." Five of the latter fragments have not yet been included in the reconstruction (fig. 10). On a field trip in July, Jolly recovered a left frontal supraorbital torus (marked "4" in the reconstruction) which appeared to fit the right side and complete the curve of the frontal bone above the orbits. However, the left is not quite symmetrical with the right, as the ophryonic groove bulges on the left, but this may be a normal variation. On our third visit I recovered two fragments about 500 yards away from the original place of discovery. The one

Comparison of some significant figures: The data for the Rhodesian, Sinanthropus and Homo Soloensis material are from Weidenreich, '43 (except where indicated)

MEASUREMENTS	SALDANHA	RHODESIAN	FLORISBURG	SINANTHROPUS	HOMO SOLOENSIS
Maximum length (g-op)	200	208 (R.S.)	199(?)	188-199 (193.6)	193-219.5 (209)
Glabella-lambda line (g-l)	192	196	..	169-183 (176.8)	174-198 (182.8)
Bregma height (above g-op line)	84	83 (85-R.S.)	87	74-81 (77.3)	68-84.5 (77.7)
Maximum breadth	?144	144.5	147	137-143 (141)	138-156 (146)
Minimum frontal breadth	102	97.5	120	81.5-91 (87.2)	..
Calvarial height	90	85	88.5	67-82 (74.6)	77.5-84 (74.6)
Frontal profile	61°	60°	69°	56°-63° (60.5°)	54°-66° (62°)
Inclination of frontal squama to g-op line	47°	45°	49°	38°-45° (42.5°)	41°-54° (45.8°)
Occipital inclination II.	?75°	68°	..	57°-68° (62.7°)	59°-73° (62.8°)
Length-breadth index	?72	69.4	75	71.4-72.6 (72.2)	66.2-76.7 (72)
Calvarial ht./ g-op line index	45	40.5	45.2	34.8-41.2 (38.5)	36.8-42.6 (39.5)
Bregma ht./ g-op line index	42	40.5	44.3	34.4-40.2 (37.6)	34.9-41.7 (37.8)

fragment (marked "2.A.") is part of the posterior end of the right parietal bone which fits accurately into the reconstruction of the lambdoid suture; the other (marked "3.A.") is the upper end of the ascending ramus of a mandible (fig. 10). Before the numerous fragments were restored I, assisted by Dr. E. N. Keen, made detailed measurements of the size and thickness, and observations on the appearance of each separate fragment. The fragments were classified and marked with India ink on their endocranial aspect.

Thus the Saldanha skull (so styled because Hopefield lies within the greater Saldanha Bay area), reconstructed from 27 fragments by Professor M. R. Drennan, assisted by Dr. E. N. Keen and myself, at present consists of a fairly complete "cap" or vault. There is a striking resemblance between it and the Rhodesian (Broken Hill) skull in general outline and measurements (fig. 2 and table 1). On the other hand, there are also features of similarity between it and the *Sinanthropus-Pithecanthropus-Homo soloensis* group, especially the latter (fig. 3). It is not necessary in this short paper to repeat what has been said before, because Weidenreich's discussion in his masterly monograph on the skull of *Sinanthropus* ('43), where he dealt with the relationships between the Far East fossil group and Rhodesian man holds good, by and large, for the incomplete Saldanha skull. The latter is characterized by a moderately low braincase (but higher than any skull in the Far East group) with its greatest breadth apparently near its base (fig. 9), and a relatively flat forehead separated from massive supraorbital ridges by a distinct ophryonic groove (figs. 6 and 7). The occipital crest is prominent and has a downward tilt. The supreme nuchal line is also obvious (fig. 9). The sulcus supratoralis is fairly well marked. However, the torus occipitalis does not seem to have the typically undermined edge which is seen above the nuchal plane of the Ngandong skulls. The fracture just below the protuberant torus prevents any conclusive opinion as regards the position of the foramen magnum or as regards the appearance of the nuchal plane, but there should be little reason to believe that it differs markedly

from that in the Rhodesian skull: a different view is expressed by Drennan ('53a,b) who stated that he considered that the nuchal plane would have been directed posteriorly and that "indications from the attachments of the muscles of the nape of Saldanha man's neck point to his having had the crouching posture of Neanderthal Man, whereas the Rhodesian skull shows that he held his head erect like sapient man." Weidenreich ('43) stated that in the Rhodesian skull the occipital foramen has a distinct central position which is a specific hominid

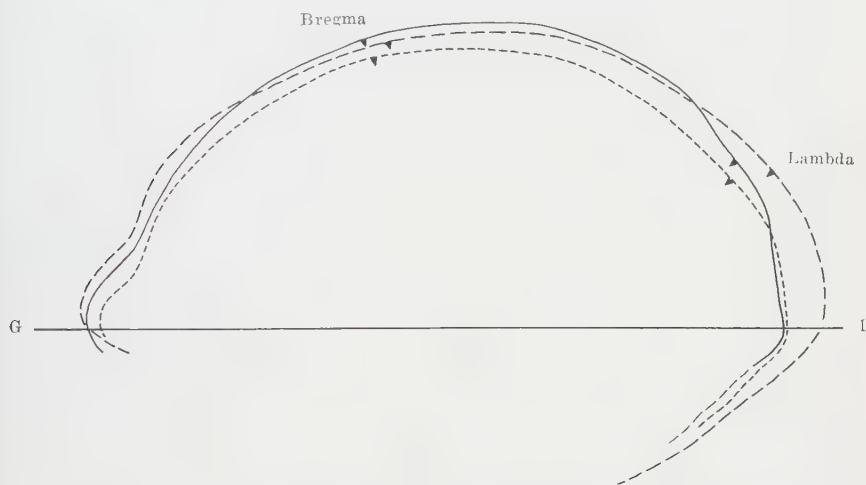


Fig. 3 Sagittal dioptographs orientated in glabella-inion plane, indicating relationships between Saldanha Skull ———; La Chapelle-aux-Saints Skull — — —; and Sinanthropus XII (Skull I, Locus D) · · · · · (after Weidenreich).

character. Furthermore, Sergi ('30, '32) and others indicated that Neanderthals did not crouch or walk with a "simian stoop," and Schultz ('42) proved that, in the balance of their heads, the Neanderthals also behave as does modern man and do not approach conditions of the anthropoids. Mainly on the above supposition, Drennan bases his view that "Saldanha man is anatomically a more primitive variety of the Rhodesian race."

The general thickness of the Saldanha skull is interesting, though not nearly as impressive as that of the Sinanthropus

adolescent skull (discovered on December 2, 1929). The average thickness of the Saldanha frontal bone is 10 mm centrally and 6 mm laterally; the parietal bone averages 10.5 mm parasagittally and 7 mm near the temporo-parietal suture; the occipital squama is very thick, averaging 8 mm in each superior cerebellar fossa and 12 mm opposite the internal crest between the fossae. The supramastoid bulge of bone has a maximal thickness of 13 mm.

The maximal thickness of the supraorbital torus is 20 mm medially and 16 mm laterally, as compared with 21 mm and 15 mm respectively in the Florisbad skull; 19.6 mm and 11.2 mm respectively in *Sinanthropus* II (Weidenreich, '43); and 20 mm and 20 mm respectively in the Rhodesian skull. In the latter there is a bulge over the center of the orbit which gives a thickness of 23 mm. The shape and curvature of the tori differ in the Saldanha and Rhodesian skulls. In the former, the anterior surface curves evenly outward (with the convexity upward) in the same vertical plane, while in the Rhodesian the convexity is less accentuated and the anterior surface has a tortuous appearance, so that medially it is in a vertical plane while laterally it is in a semi-horizontal plane with the anterior surface looking upwards and outwards. The maximum breadth of the supraorbital ridges is 122 mm in the Saldanha (though a small piece is broken off), 136 mm in the Florisbad, and 139 mm in the Rhodesian skull. The left frontal sinus is compartmented and occupies the whole of the supraorbital torus, while the right sinus is very small, loculated and rounded (as seen on X-ray photographs).

The inclination of the frontal bone differs markedly between the Saldanha and Florisbad skulls, but the calvarial height is approximated in them, though the highest point is slightly nearer the bregma in the Florisbad skull. The highest point in the Rhodesian skull is just behind bregma, well ahead of the same point in the other two skulls. The inclination in the Rhodesian and Saldanha frontal bones is almost identical.

A modified frontal chord, using glabella instead of nasion, reads 116 mm for the Saldanha skull, while it is 121 mm in the

Rhodesian; and the median frontal ridge in the latter is more angular and prominent. The parietal chord is 109.5 mm in the former and 113 mm in the latter, and the occipital chord is 54.5 mm in the former and 59.5 mm in the latter. The figures for the occipital chord are particularly interesting because, despite the fact that this is greater in the Rhodesian, the latter also subtends a larger angle at the lambda between the right and left lambdoid suture lines, namely, 160° compared with 130° in the Saldanha. The lengths of the lambdoid sutures in Saldanha, though incomplete, are estimated to approximate those in the Rhodesian, namely 91 mm on the left and 90 mm on the right. Thus the "surface area" of the Rhodesian occipital bone, above the torus occipitalis, is the greater of the two. In *norma lateralis*, the "bun-like" bulge in this region below lambda is far more marked in the Rhodesian skull (fig. 2), but this does not account for the apparent discrepancy in the surface areas. Moreover, this bulge is a variable feature and noticeable in many modern skulls, and its significance is as yet doubtful. Drenman considers this difference in occipital bulging a feature in favor of "the Saldanha skull diverging morphologically from the Rhodesian type." Furthermore, in *norma occipitalis*, there is a marked difference in appearance between the two skulls. The Saldanha appears to have a degree of parietal bossing which tends to flatten the horizontal plane of the skull in a line taken across vertex (fig. 9), while in the Rhodesian there is a marked sloping or falling away of this plane towards the mastoids. Despite these features, the maximum breadth in the two skulls appears to be in a line across the supramastoid regions and is approximately equal. A true torus angularis is not visible.

In the Saldanha skull the anterior ends of the temporal lines, arising as a bifurcation of the temporal crest or ridge behind the supraorbital tori, are prominent. The left superior temporal line kinks upwards at stephanion producing a high temporal arc which soon fades out. On the right side, the kinking is not obvious. The bregma-stephanion chord is 47.5 mm on each side in the Saldanha skull, while in the Rhodesian the

reading is 58 mm on each side. However, though this figure is conventionally recorded, I have found so much variation in it in series of hundreds of skulls of "known racial" groups that these slightly variable figures here cannot be taken to be of much significance other than to record the position of the two points.

I feel that it is unnecessary at this stage to compare the Saldanha skull with the various Neanderthals recorded, as only the protuberant supraorbital ridges definitely indicate the Neanderthal "streak" in this specimen. It is considered more logical at this stage to compare the "local" African fossil types, namely Rhodesian and Florisbad. The latter has been dealt with in greater detail in another paper (to appear in the *Indian Journal of Palaeontology*). The Eyasi skull (misnamed *Africanthropus njarasensis* by Weinert in 1939) has not been compared in this paper as a cast is not available here. Leakey ('47) assigned it to the East African Upper Pleistocene (Gamblian pluvial) period.

A detailed description of the endocranial cast of the Saldanha skull is yet to be completed.

CONCLUSIONS

The importance of the discovery of this incomplete skull may be stated as:

1. It confirms that the Rhodesian skull is no isolated, abnormal or pathological type of primitive man.
2. The Saldanha skull is akin to a similar region of the Rhodesian skull; such differences as have been mentioned in this paper may be regarded to fall within the limits of individual variation. It thus establishes an African Neanderthalian quite different in many respects from the European variety and resembling to some extent the larger specimens of the Asiatic Neanderthalian, *Homo soloensis* (as far as can be determined from the incomplete material available).
3. It provides a probable South African hand-axe man who was perfecting a transitional stage between the coastal South African Earlier and Middle Stone Age Cultures. This appears

to have taken place during an Upper Pleistocene period, probably an early part, if one accepts the relationship between the fluorine dating of the Saldanha skull and the extinct fossil fauna.

It appears that Weidenreich's original classification (1928 and 1943) of the Neanderthal group into *Homo primigenius europaeus*, *Homo primigenius asiaticus* and *Homo primigenius africanus* is beginning to bear more weight. In this respect, I would like to quote two appropriate sentences of Franz Weidenreich's ('40) with which I readily concur:

"... for it proves that the so-called Neanderthal Man of Europe, notwithstanding his uniformity when compared with the Rhodesian Man of South Africa ⁴ or the *Homo soloensis* of Java, has produced certain regional variations which are equivalent to racial differences of today," and in similar vein, "while Man was passing through different phases, each of which was characterized by certain features common to all individuals of the same stage, there existed, nevertheless, within such community different types deviating from each other with regard to secondary features. These secondary divergencies have to be rated as regional differentiations and, therefore, as correspondent to the racial dissimilarities of present Man."

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⁴ Broken Hill is in Northern Rhodesia, *not* in South Africa.



4 Norma verticalis. Note parietal bossing, and great anterior projection of supraorbital tori with a distinct central "sulcus."



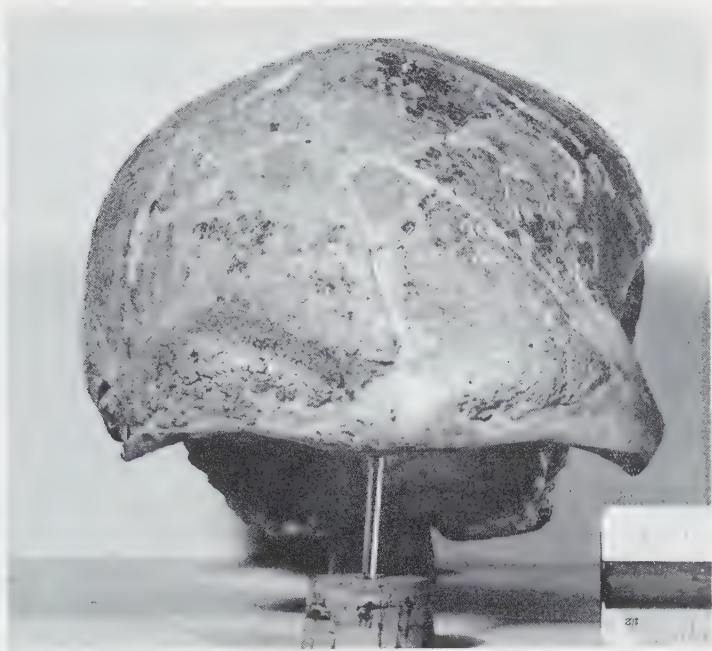
5 Endocranial aspect. Note orbital plate with erosion into right frontal sinus.



6 Right oblique view. This view emphasizes the "vertical plane" of the anterior surface of the supraorbital torus, and also the ophryonic groove.



7 Norma lateralis, right.



8 Norma facialis. There is a slight flattening out of the left ophryonic groove.



9 Norma occipitalis. Central area of nuchal plane is plaster reconstruction.



10 Cranial fragments not incorporated in reconstruction with a part of ramus of mandible on the right (lingual aspect).

SOME FACTORS TO BE CONSIDERED IN THE STUDY OF LUMBOSACRAL FUSION

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FIVE FIGURES

In 1951 mechanical stress was emphasized by Thieme, in the *American Journal of Physical Anthropology*, as a factor predisposing to fusion of the 5th lumbar vertebra to the sacrum. Statistics derived from measurements were presented to substantiate the opinion that the position of the sacral promontory above or below the arcuate line of the pelvis was related to the mechanics of weight-bearing, and that fusions of the lumbosacral articulation developed, presumably during postnatal life, in response to the stress of upright posture. Other observations and theories on lumbosacral fusion were not discussed. This mechanical theory is so unrelated to many of the known facts that at first glance it would seem unnecessary to call them to attention. Since then, however, no critical comment has been aroused; the present brief review therefore appears to be in order.

In the first place, there has been an unnecessary complication of the pathological with the morphological. Bony fusions at articulations often are the result of acquired disease. Destructive processes such as tuberculosis, rheumatoid arthritis, and degenerative osteoarthritis may lead to bony ankylosis at the lumbosacral articulation and at other joints, many of which are not weight-bearing and not subject to significant

¹ I wish to thank Dr. E. W. Dempsey, Dr. Mildred Trotter, and Dr. R. J. Terry of the Washington University Department of Anatomy, St. Louis, Missouri, for making available to me the Terry collection of skeletal material used in this study, and Mr. M. W. Rhoades for his excellent photographs.

mechanical stress. Such pathological fusions are of great clinical significance but are of no anatomical significance except to be recognized and excluded from series when genetic or developmental fusions are under consideration. In the reference cited it is implied that osteophytes are produced in response to normal stress. The pathologist, however (Pommer, '13), regards osteophytes as a response of damaged cartilage and bone which results in a reactivation of endochondrial ossification. This occurs only at the margins of diseased joints, most commonly in osteoarthritis. Florid examples are seen when such damaged joints are used without protective responses on the part of the patient, as in tabes dorsalis, or syringomyelia, resulting in the so-called Charcot joint. Another classic example of osteophytes are Heberden's nodes at the distal interphalangeal joints. Since osteophytes characterize degenerative hypertrophic osteoarthritis in particular, the confusion of this pathological condition has been introduced into a morphological problem.

An example of lumbosacral fusion due to the interlocking of osteophytes of osteoarthritis is shown in figure 1. Figure 2 illustrates pathological fusion following a different disease, rheumatoid arthritis. In this condition the diarthrodial articulations of the vertebral column may be completely destroyed, and in healing a solid synostosis may be formed. Degenerative osteoarthritis is usually superimposed on joints incompletely destroyed by the pannus of rheumatoid arthritis; this can lead to difficulty in distinguishing the primary disease. Osteophytes are not prominent in rheumatoid arthritis, however, as shown in the example.

In these pathological fusions it is paramount to recognize the lumbar morphology of the vertebra involved. No tendency toward sacralization of the transverse processes is present. Figure 3 shows, however, that degenerative osteoarthritis can result in fusion of vertebrae where there is a morphological tendency toward sacralization. In this case pathological bone locks the centrum of L 5 to S 1 at the only site where the two bones are fused. Although the transverse

processes are completely sacralized in form, they remain entirely separate, forming a synchondrosis. The separate-ness of these bones is of morphological significance, while the pathological fusion is morphologically unimportant.

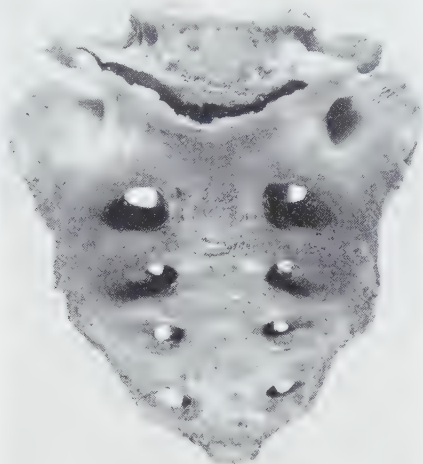


Fig. 1 Pathological fusion of L5 to S1 due to osteoarthritis. L5 is lumbar in morphology.

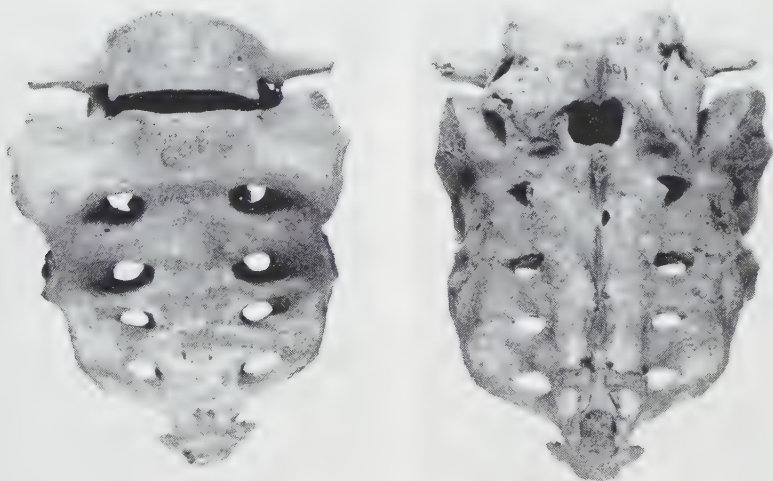


Fig. 2 Pathological fusion of L5 to S1 due to rheumatoid arthritis. L5 is lumbar in morphology.

Figure 4 illustrates selected degrees of morphological fusion of the 5th lumbar vertebra to the sacrum. These variable characters, such as sacralization and fusion on the one side, and a persistent lumbar transverse process on the other, are difficult to explain by a simple stress theory. Contrary to fusions resulting from disease, these examples show no osteophytes, nor evidence of any pathological process. Furthermore, fusions of this nature are found in embryos and fetuses and have never been observed to develop in the postnatal period.



Fig. 3 Pathological fusion of L5 to S1 due to osteoarthritis. L5 is sacral in morphology.

Comparative anatomists have long recognized variations in the level of the sacrum (the result of lumbosacral fusions, and separations), by the variable number of free presacral vertebrae in members of the same species (Flower, 1884). The evolutionary significance of this variability in mammalia was a subject for analysis by Todd ('22). Thus, the variation is well known to occur in pronograde species whose lumbosacral articulation has never been subjected to the stress of upright posture. Willis ('23) and others too numerous to list have described these variations in man in great detail.

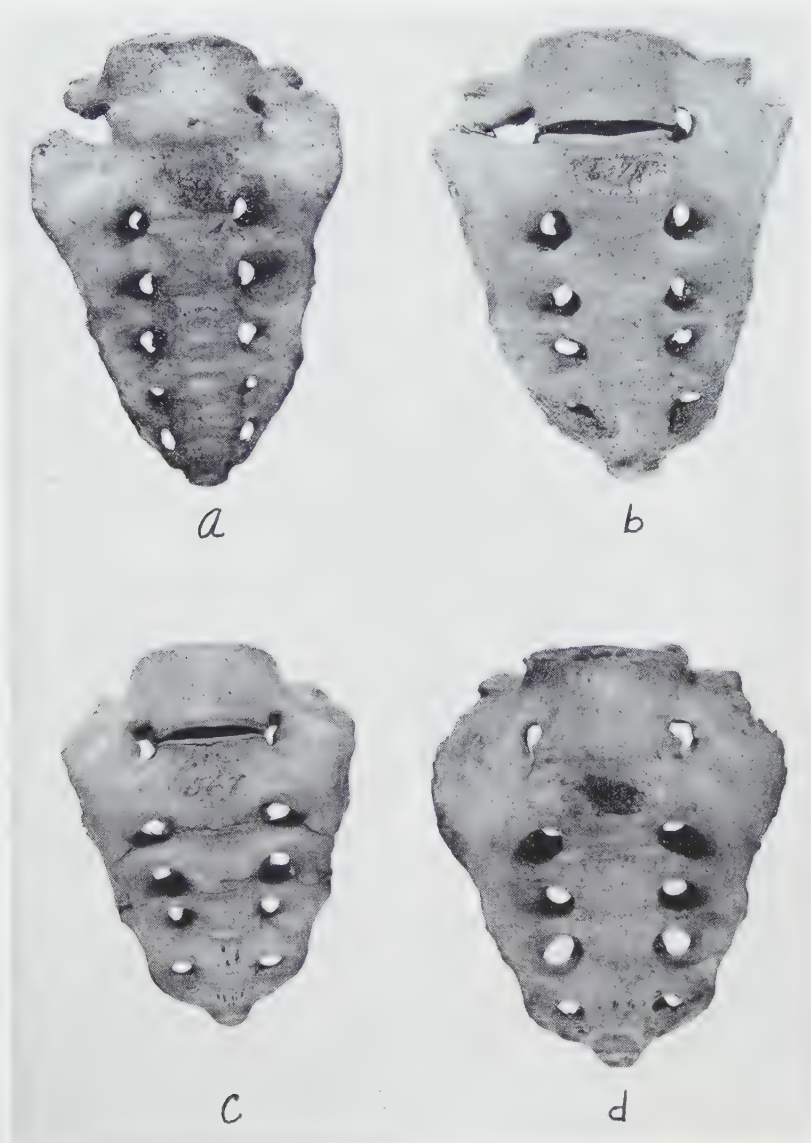


Fig. 4 Fusion of morphologically sacralized 5th lumbar vertebrae of varying degrees of sacralization. No pathological bone is present.

Keith ('23) demonstrated that fusions of vertebrae may result as part of the complicated anomalies produced by incomplete segmentation in early embryos. Recently Rothfels ('54) has shown that segmentation can be arrested in the chick embryo cultivated on media in which the metabolism of the amino acids isoleucine and valine is blocked by antimetabolites. More specifically, embryologists (Reiter, '49) describe caudal-shifting of the hind limb bud beginning in 3 mm embryos. This normal developmental migration is finished by the 12 mm crown-rump stage when the final position of the sacroiliac and lumbosacral articulations is established. These relationships are therefore settled somewhat before the mechanical influences of upright ambulation come into play.

Experimental embryologists (Holder, '49) have been able to vary the level of the sacroiliac articulation, and thereby the lumbosacral articulation, by transplantation of the hind limb buds of tailless amphibians to varying levels. It is thus clearly established by observation and experiment that the position of the hind limb bud is the controlling factor in the process under discussion.

Kühne ('32) opened the way to our present understanding that variability of the junctions of the intersegmental levels in the human spine is a genetically controlled process. This includes lumbosacral fusion, as well as separation of S 1 from the sacrum, and also cranialward and caudalward variations at the cervico-thoracic, thoraco-lumbar and sacrococcygeal levels. As long ago as 1876, Rosenberg concluded that variations in the vertebral column which transmuted characteristics of the segments forward, toward the head, had an evolutionary significance. Adolphi ('05) recognized that the direction of variability at the intersegmental levels could be caudal as well as cranial, but that any individual spine always varied in the same direction at the various levels, that is, either cranially or caudally, and never cranially at one level and caudally at another. For example, lumbosacral fusion between L 5 and S 1 does not occur in an individual with ribs of the first lumbar vertebra, the 20th in the series; however,

lumbar ribs, on the 20th segment, frequently accompany lumbarization of the first sacral segment.

At this point it must be emphasized that one cannot regard the isolated lumbosacral articulation in any given case and differentiate degrees of lumbosacral fusion from degrees of lumbarization of the first sacral element. It is absolutely necessary to begin with the atlas and count the vertebrae in each skeleton to be studied. The gross similarity of the bones in figures 4 b and 5 is an example. In Terry collection Skeleton



Fig. 5 Lumbarization of S1, indistinguishable from fusion of L5 to S1 unless the entire vertebral column is examined.

637R (fig. 4 b) there are cervical ribs, associated with marked diminution of size in the 12th thoracic ribs, and the 5th lumbar, the 24th, is that vertebra fused to the sacrum, sacral in form. This is an example to cranial-shifting of the intersegmental borders of a strong degree of expression. In Terry collection Skeleton 896 RR, figure 5, there are 7 normal type cervical vertebrae, 13 pairs of ribs one one side (a lumbar rib), and there are 24 free presacral elements. The condition illustrated is therefore a tendency for caudal-shifting, with the first sacral vertebra becoming lumbar, a morphological about-face

entirely different than that shown in Terry collection Skeleton 637 R. This confusion of similarities may not have occurred in the series reported by Thieme. His failure to define clearly the condition of the upper vertebral segments, however, leads to the conclusion that both anomalies may have been indiscriminately included in his report.

Kühne ('32, '36) observed the *direction* of these variations at the intersegmental regions of the spine in several generations of families and in siblings in a large series, confirming Adolphi, and clearly proving that hereditary factors were involved. In his subjects cranial-shifting (Cr) dominated caudal-shifting (cr) and in a statistical distribution suggesting hereditary control by a single pair of genes. Kühne's observations in humans have been extended by Steiniger ('38) and by others.

Sawin ('37-'46), working with rabbits, and Green and Green ('46), with mice, have varied the position of the intersegmental borders of the spine in breeding experiments. Their results do not dispute Kühne's primary concept that genetic factors are of fundamental importance, although in these animals a single pair of genes and simple gene dominance does not afford a complete explanation of the process.

In summary, the evidence to date from a variety of disciplines, embryology, genetics, comparative anatomy, human anatomy and pathology, harmoniously indicates that morphologically significant fusion of vertebrae at the lumbosacral level is a complex process related to other intersegmental variations in the spine, and that the process is genetically influenced and determined at an early embryological stage. An excellent and complete review of the significance of vertebral anomalies by Theiler ('53) is recommended to all who are interested in a more detailed account. With him we offer the following quotation, from Mall ('08), in conclusion: "The more . . . theory is tested by experimental methods, the more all simple mechanical explanations suffer, and it seems to me that all of them will have to be abandoned."

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ETIOLOGY OF RUPTURED INTERVERTEBRAL DISCS.—In a roentgenographic and anatomical study of 160 lumbar portions of spines of cadavera, a correlation was found between disc ruptures and marginal osteophytes. Such osteophytes were present only in ruptured discs and the extent of bony formations was, as a rule, dependent upon the extent of disc change. Thus, the occurrence of osteophytes was an indication of disc degeneration and rupture. This fact was used in a comparative study of the lumbar portion of the spine taken from a modern population on the one hand and a prehistoric population on the other. The result of this comparison was as follows: Modern man has more and larger osteophytes in the lower lumbar region than prehistoric man; at the lumbosacral disc the occurrence was higher in the modern female than in the male, while this difference was not found in the prehistoric material. It was therefore supposed that something in the modern way of living (such as wearing shoes with heels) increased the lordosis, which resulted in increased pressure on the posterior portion of the lower lumbar discs.

With [this and other] premises, experiments were carried out on a series of rats' tails in order to study the effect of constant asymmetric pressure on the intervertebral discs.—Knut Lindblom. Experimental ruptures of intervertebral discs in rats' tails: A preliminary report. *J. Bone and Joint Surg.*, vol. 34-A, no. 1, pp. 123–128, January, 1952.

DEMONSTRATION OF THE INTRINSIC VASCULAR PATTERN OF COMPACT BONE

A VITAL "SPLIT-LINE" TECHNIC

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TWO FIGURES

INTRODUCTION

The consideration of compact bone morphology as an expression of its response to the functional demands placed upon it continues to be worthy of investigation. If it is assumed that the orientation of the units of compact bone tissue, the osteones (Haversian Systems) as well as that of lamellar bone, is a reflection of this response, then technics which demonstrate this orientation are experimentally useful. The use of one such technic, the split-line method of Benninghoff ('25), is based on three postulates. First, it is held that the split-line pattern satisfactorily shows the orientation of the osteones and lamellar bone. Secondly, this orientation is often considered to be determined primarily by functional demands. Workers utilizing these two postulates assume the third; that the oriented bone is homogenous in morphology and constitution.

Anthropological interest has recently been directed towards the phylogenetic and ontogenetic implications of results derived from the application of this traditional split-line method to a comparative series of primates (Seipel, '48; Ulutas, '52; Tappen, '53). The value of these implications depends on the correctness of the three postulates of the method.

¹ Post-doctoral fellow, National Institutes of Health.

Aside from these theoretical problems, certain technical aspects of the split-line method hamper its fuller utilization. Prolonged preservation of decalcified material is a problem which is implicit in its method of preparation. The distortion of the decalcified bone by the puncture is, perhaps, not critical; but the interconnection of these induced splits by an approximate line leaves much to be desired. While it is undoubtedly true that the resulting lines do reflect the *mean* course of the osteones, the existence of deviations from this artificially smoothed pattern remain unobserved.

Both of these technical problems would be overcome by a vital staining technic which would selectively and permanently stain either the soft tissue walls of the intraosseous blood vessels, or so stain the immediately adjacent bone in such a manner as to demonstrate the direction of the vessels. If, in addition, the dye utilized is sufficiently intense, the direction of these vascular channels will make clearly visible the more minor variations in the direction of the osteones. Such a technic is described in this paper.

MATERIALS AND METHODS

The use of Chlorazol Fast Pink (C.I. no. 353) was first reported by Modall ('39) for use as an anticoagulant. In the course of physiological experiments on cats, in which this dye was used for the former purpose, it was noted that the bones of the sacrificed animals showed a diffuse pink coloration. This aroused interest as to the site of staining. The following work was originally undertaken to ascertain this point. In this experiment, 5-20 cm³ of a 5% aqueous solution of this dye was administered intravenously to 10 adult cats, averaging 2 kg in weight. One to two hours later the animals were sacrificed, the heads being prepared by boiling in water for several hours and then being bleached overnight in 3% H₂O₂. The heads of two additional cats were prepared by the traditional split-line technics involving decalcification. Ground sections of bone were prepared from

areas in the cat skull which very clearly showed these intensely stained lines.

RESULTS

The vital administration of this dye is quickly followed by the spread of the color to all parts of the animal. The skin, mucous membranes and conjunctiva color visibly. The skulls of the injected cats uniformly show an overall pinkish cast. No apparent loss of coloration occurs as a result of their preparation. A pattern of more intensely stained red lines is clearly visible on the surface of the skulls (figs. 1 and 2). Comparison of this pattern with the split-lines obtained in the control cats demonstrates their essential identity.

The body and especially the ramus of the mandible, the maxilla, premaxilla, zygoma and portions of the temporal, all clearly show these lines. The calvaria is essentially without pattern, as was the base of the skull. The palate gives a stippled appearance, or at best, a series of short lines. The sutures are deeply stained.

Closer inspection of the pattern obtained on the facial skeleton of the injected cats reveals that the course of these lines is a good deal more irregular than those obtained by connecting the splits on the controls. While the *mean* direction of the bone structure is shown identically by both methods, the injected material distinctly indicates the rather sinuous course of the structures within the outer cortical layers.

Microscopic examination of the ground sections reveals that the stain is restricted to the innermost two or three concentric layers of bone immediately surrounding vascular channels of large diameter. The diameter of these channels is about 5 times that of the neighboring mature osteones. The stained structures represent immature osteones still in the process of formation. The parallelism between the orientation of the mature and immature osteones — that is, between the intensely stained lines produced by this vital technic

and the split-line pattern, is confirmed. The transversely penetrating Volkmann's canals are also shown. Sectioning of the injected cat skulls in various planes demonstrates that the deeper structures are also stained, affording an opportunity to study their course in sub-cortical areas.

DISCUSSION

The experimental approach of physical anthropologists to problems of bone structure is aided by this method. Its advantages are twofold. First, as no prior decalcification is required, the difficulties of stable preservation of the material for indefinite periods is overcome. Second, there can be no question of the production of artifacts in the observed pattern of osseous orientation.

The staining obtained with Chlorazol Fast Pink is similar to that achieved with other acid-azo dyes (Swigart and Williams, '52). Experiments with Chlorazol Fast Pink, reported elsewhere, tend to confirm this hypothesis (Moss, '54).

The interpretation of patterns

Histological considerations. The following discussion will limit itself to consideration of the osteones. These units form, by far, the greatest portion of the compact bone. I am not aware of any conclusive evidence, at this time, which materially differentiates between this type of compact bone and lamellar bone in regard to the factors discussed below.

Critical examination of the data in the literature does not substantiate the validity of the three postulates upon which the interpretation of the pattern of osseous orientation are based.

The mode of formation of the osteones requires that the long axis of any osteone must lie parallel to its centrally placed vascular structures. The growth of the immature osteone occurs by a concentric apposition of bone which occasions an increasing constriction of the lumen of the centrally placed vascular area. However, the osteone is not to

be thought of as a simple structure. In any system of osteones frequent variations are found in the width, length and direction of the single osteone. Furthermore, vascular communication between osteones produces bifurcating patterns of interconnected osseous units. In addition, within a given bone, regional differences are to be found (Koltze, '51). Alteration of bone morphology is found to be characteristic of differences in age and in the rate of growth of bone (Amprino, '47). These histological details underlie the mechanical response of bone to imposed forces (Tischendorf, '52).

Consideration of the data obtained at the submicroscopic level of osseous organization makes it clear that the degree of calcification of an osteone stands in direct relation to its age, the relative difference being of the order of 25% (Amprino, '52). Osteones sampled from various depths of the same cortical area exhibit statistically different degrees of calcification, as do those from different cortical areas (Rogers et al., '52). Moreover, the actual crystalline structure of the bone salt is also a function of time, the older osteones being far more stable in constitution and configuration (Neuman, '50). The mechanism of staining of Chlorazol Fast Pink, in these experiments, appears to correlate with the state of the newly formed bone in the immature osteones. The mature osteones are unstained.

It may be concluded that a pattern of osteone orientation, produced by any method, falls far short of accurately portraying the organization of the underlying tissues. Any interpretation which is based on the assumption of a *mean* direction of osteones, and which, furthermore, implies morphological and constitutional homogeneity to these osteones, will overlook much that is critical. It is exactly these factors which must be considered in any attempt to correlate the structure and the function of bone.

Physical considerations. Aside from histological assumptions, additional functional interpretations are frequently made of the split-line patterns. In order that any discussion

of these patterns be fruitful, it must be based on a clear understanding of the physical nature of the material.

Bone is organized to give the greatest strength with the least amount of material. However, the fact that a bone is organized to resist the externally applied forces of compression, tension and shear does not necessarily imply that these forces are the factors which determine, primarily, the structure of the bone. The imposition (loading) and withdrawal (unloading) of these forces are constantly changing as a bone moves through a range of motion. The morphology of a bone represents a compromise between the requirements of these varying forces. A bone is normally elastic (assumes its normal shape when unloaded) so that the strain (change in linear dimension) induced by loading does not threaten the integrity of the structure. Indeed, a given system of osteones may function as a "compression" system or as a "tension" system, depending on the site of application of the loading. As this site is shifted, the "neutral axis" of the bone shifts (Pauwels, '50). Although bone is non-isotropic (does not have the same physical properties in every direction) (Dempster and Liddicoat, '52) the orientation of the osteones does not become *critical* until the bone is loaded beyond the normal range of imposed forces. In this light, we should observe, for example, that the loading of the facial skeleton produced by the muscles of mastication never, normally, threatens the integrity of the bones. A recent review of some of these matters is given by Evans ('53).

It is, evidently, difficult to ascribe the mean direction of a given osteone system, no less the direction of a single osteone, to a single loading force. To interpret such an oriented system on the assumption that the functional requirements of a bone are the primary morphogenic agents is equally hard. Abundant evidence is at hand to make it seem probable that the functional orientations are only secondarily imposed on the basic, intrinsic pattern of the bone. See Fell ('53) for a recent review of these data. While these secondary

mechanical forces undoubtedly increase in significance with age, and may be responsible for the maintenance of form (Washburn, '47), rigorous proof is still lacking that these extrinsic forces are competent morphogenic agents, *per se*. It appears more likely that they provide an environment within which the intrinsic factors may be expressed. The significance of the observations reported in this paper, that the occurrence of numerous oriented patterns of immature osteones in an adult animal is most marked in the facial skeleton as opposed to its lack in the neural cranium, remains unclear at this time.

Specifically, it remains doubtful that a given split-line pattern may be attributed to the action of a given group of muscle fibers which load a given portion of a bone to produce a certain range of motion. Observation of all sites of attachment of the masticatory musculature, for example, will show great diversity in osteone direction considered in relation to the orientation of the muscle fibers (see Siepel, '48).

CONCLUSIONS

The intrinsic osseous vascular patterns are capable of demonstration by a vital technic. The material produced by this method has a two-fold advantage over that produced by traditional technics. The material does not require prior decalcification, and the resulting patterns more accurately demonstrate the orientation of the osteones.

However, the correlation of the patterns obtained with this method, or by any other method of demonstrating osteone direction, with the function of the bone must take into account not only the variations in morphology and constitution of the bone, but also certain physical considerations.

The attempt to interpret the orientation of a system of osteones as being due primarily to the imposition of an external set of forces is rejected as being an excessive oversimplification. Any further application of such an interpretation to anthropological problems therefore seems dubious.

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PLATE

PLATE 1

EXPLANATION OF FIGURES

1 Zygomatic bone and zygomatic process of the temporal bone of the cat. The zygomatico-temporal suture is clearly seen. Animal injected vitally with Chlorazol Fast Pink.

Note the sinuous, irregular, course of the immature osteones in the compact bone of the zygoma, at the left. These lines are *intensely* stained in the original preparations. $\times 3.5$.

2 Lingual surface of the cat mandible, vitally injected with Chlorazol Fast Pink.

Note that while the immature osteones are regularly arranged on the edge of the coronoid process, they follow a more irregular course just above the mandibular foramen. $\times 3$.





NEW MEGANTHROPUS FIND.—A probable additional mandible of *Meganthropus* is reported in a preliminary note by P. Marks in the *Indonesian Journal for Natural Science* (Madjala Ilum Alam Untuk Indonesia), volume 109 (1953), pp. 26–33. The specimen was collected in the Sangiran vicinity in September, 1952, and is believed to come from a conglomerate bed which is either a layer within the Putjang (Djetis) beds, or the “Grenzbank” between these and the Kabuh (Trinil), and accordingly may be of either late Lower or early Middle Pleistocene age.

The specimen, not yet cleaned of matrix, consists of the body from the region of the left M_1 to the base of the right ascending ramus. It is badly fractured, with a portion bearing the alveoli or roots of P_3 to M_2 on the right side being displaced forward so that it extends beyond the symphyseal region. The right M_3 , somewhat displaced lingually, is the one tooth in good condition. This tooth has a tuberculum sextum, and a number of details reminiscent of *Gigantopithecus*, according to author (though apparently not a close resemblance as to general shape — WWH). Its length and breadth diameters are 15.5 and 13.0 mm, and the indicated diameters of the broken M_1 and M_2 are given as 14×13.0 and 14.5×13.0 mm respectively.

The body is bulky, with the root of the ascending ramus wide to the buccal side. There is a pronounced incisura submental, as in the jaws of the type *Meganthropus* and of *Pithecanthropus*, *Sinanthropus*, and Heidelberg. Thickness at the left M_1 is 22 mm, and heights are given as follows: at the symphysis, 37 mm; at P_4 (left?), 42; and between M_2 and M_3 , 47.

SEX DETERMINATION OF THE SKELETON BY GUESS AND BY MEASUREMENT

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ONE FIGURE

In a recent issue of *Human Biology*, Hanna and Washburn ('53) have added another article to a series dealing with the sex determination of the pelvis in various racial groups (see also Washburn, '48, '49). This time the Eskimos, as represented in the U. S. National Museum collections, are the subject of study. Of this group of pelves, it is asserted that ". . . there are very few cases which are intermediate in character, and . . . the sorting . . . which is based only on the ischium-pubis index and the sciatic notch, separates over 95% of the total series into two very distinct groups" (p. 25). However, instead of showing the distribution of these features separately, as in previous articles, the authors have combined them in a scattergram. Since the resulting distribution is decidedly bimodal, the authors have inserted a diagonal line to show how they would divide males and females without leaving any in doubt.

As a check on the reliability of these sex determinations as made by measurements, the authors compare their results with those of Hrdlička as made by "guessing"¹ the sex of the skulls from the same skeletons. Although skull and pelvis are not fully comparable in this connection, there was disagreement in only 8 out of 173 cases. In 7 of these cases the authors see no reason to change their opinions and hence consider Hrdlička to be in error. The sex of the remaining case is conceded to be "in reasonable doubt."

¹ The authors use this expression (p. 26) to characterize the procedure whereby sex is assigned without recourse to measurements.

From all this the authors draw a conclusion which represents a point of view not previously expressed, namely, that their method of sexing “. . . is more useful than the traditional anthropological one of depending on personal judgment because: the basis for the assignment of sex is explicit and can be improved, a beginner can do as well as an expert, and it automatically adjusts to the variations in new series” (p. 27). The implication of this and other statements is that the authors’ method can and should be taught because the traditional method of sexing is incapable of being taught.

There is no doubt that this series of papers has focussed attention on the extreme sexual dimorphism of the human pelvis. Although this is not an altogether new discovery, the facts were no longer generally appreciated and needed restating. The manner of the restatement is ingenious. Here then is new assurance that skeletons from archaeological sources with pelvis (or at least one innominate each) can be reliably sexed in 95–98% of all cases. Here, too, is an objective means by which beginners can convey to others a feeling of trust in their sexing of skeletal remains. But when the authors suggest teaching this method in place of developing personal judgment, are they not falling into the error of the self-improvement courses advertized in the pulps which can be taught “in three easy lessons”? And is Hrdlička a good representative of the traditional school?

Let us consider the second question first. I have pointed out elsewhere (Stewart, '39, p. 26) that G. M. Morant once expressed doubts about Hrdlička’s sexing of Eskimo skulls, and (Stewart, '43, p. 266) that Hrdlička tended to place too high reliance on size (capacity) in sexing skulls. This tendency on the part of Hrdlička, together with his lack of insistence on judging sex from the skeleton as a whole, constituted his particular bias in this matter. Actually, Hrdlička’s judgment of a skeleton for sex was among the best, yet he thought nothing of changing an earlier opinion when the skull measurements seemed out of line; that is, if they seemed to him either too large or too small for the

assigned sex, he would change the designation and thereby reduce the range of variation. How such a bias worked in practice is shown by the cases of disagreement cited by Hanna and Washburn:²

U.S.N.M. NO.	APPARENT SEX (Hanna and Washburn)	SEX RECORDED IN ACCESSION RECORD	SEX REPORTED BY HRDLIČKA IN CAT. OF CRANIA ('42)
227484	Female	Male (AH) ¹	Male
332533	Male	Male? (TDS)	Female
332541	Male	Female (TDS)	Female
339033	Male	Female (AC)	Female
342449	(Mixture: Innominate old, skull young)		
345304	Male	Female (MSG)	Female
345310	Male	Male (MSG)	Female
346069	(Mixture: Pelvis old, skull young)		

¹ Cataloguer identified by handwriting: AH = Aleš Hrdlička, TDS = T. D. Stewart, AC = Alexander Casanges, MSG = Marcus S. Goldstein.

In 5 of these cases Hrdlička assigned the skulls to the female sex, whereas Hanna and Washburn decided that the respective innominates were male. In another case, Hrdlička decided that the skull was male, but Hanna and Washburn found the pelvis to be female. On examining the skulls themselves, it is hard to understand why Hrdlička did not call all of them female; they are small and lack the usual characteristics of males:

U.S.N.M. NO.	MODULE	BROWRIDGES	ORBITAL BORDERS	MASTOIDS	CHIN
	<i>mm</i>				
227484	151 ¹	Submedium	Sharp	Small	Rounded
332533	147	Very slight	Sharp	Submedium	Pointed
332541	148	Slight	Sharp	Submedium	Pointed
339033	150	Submedium	Rounded	Very small	?
345304	150	Slight	Sharp	Small	Square
345310	146	Submedium	Sharp	Submedium	Pointed

¹ Average for male Eskimos is near 154.

My own examination of the pelvis leads me to agree with Hanna and Washburn that 227484 is most likely a female,

² I am indebted to the authors for allowing me to examine their data.

and that 332533, 345304 and 345310 are males. Of the sex of 332541 and 339033 I am less certain.

The ischium-pubis indices in the two uncertain cases are 85 and 90, respectively. In Negroes of known sex this is the area where the indices of the two sexes overlap in their distributions (Washburn, '48, fig. 1; '49, fig. 1). In Whites of known sex, on the other hand, the overlap in this index is higher: 90-95 (Washburn, '48, fig. 1). The occurrence of a distributional overlap in two races gives us reason to believe that there is one in the Eskimos, but we have no way of knowing where, on archaeological material, it is located. This uncertainty makes the assignment of sex to Eskimo pelvises in the intermediate range rather arbitrary.

Hanna and Washburn are doubtless aware of this argument because they do not judge the sex of the Eskimos on the ischium-pubis index alone; they consider also the sciatic notch and get some support from the interiliac index. In this connection they point out that a high ischium-pubis index (over 92) is almost invariably accompanied by a broad notch (as expressed as an angle, over 60°), and conversely, that an index below 90 is accompanied by an angle of less than 70° . According to this rule, the two uncertain cases mentioned above, which have angles of 56° and 51° , respectively, would have to be males. However, considering Washburn's findings on the Bantu of known sex ('49, fig. 2), there is a greater distributional overlap in the form of the notch than in the ischium-pubis index.³ Again, therefore, just as for the ischium-pubis index, it would appear that the Eskimos must have a distributional overlap in the angle of the notch and that, even when used in combination with that index, a notch of intermediate form would not make the assignment of sex less arbitrary.

The addition of the third character, the interiliac index, to this combination might increase the possibility of correct sex identification, but as yet we do not know its true distribu-

³ Washburn here used maximum width rather than the angle to express the form of the notch.

tion for the sexes. The distribution given by Hanna and Washburn for the Eskimos is based on sex assignments as made by these authors using the two characters discussed above.

Summarizing the arguments thus far, I feel that Hrdlička's ability to sex skulls by the traditional inspectional method, and the method itself, are unfairly represented by the data in his Catalog of Crania which Hanna and Washburn have used as a check on the reliability of their metrical method, the reasons being: (1) that sex is more difficult to determine from the skull than from the pelvis, (2) that Hrdlička had a personal bias on the correlation of skull size with sex and failed to correct this bias by reference to the pelvis, and (3) that there is still reasonable doubt about the true sex of not only the specimens under examination but of the 2-5% which would be expected to overlap in sex characteristics.

We come now to the other question asked above, which can be stated also as follows: Is it not misleading on the basis of the evidence now available to advocate the teaching of sex determination by the authors' method of measurement in preference to the traditional method of inspection? Perhaps I am interpreting the authors' remarks too literally when I take them to mean that their method of sexing the skeleton by *measuring the pelvis* should replace the traditional method in which the *whole skeleton, or whatever part is available, is inspected*. They may mean that measurements should replace inspection only so far as the pelvis is concerned. In the latter case students still must learn to look for sex differences in the rest of the skeleton and therefore might as well include the pelvis in their study. Any observer can learn quickly to distinguish by eye the better differentiated male and female pelvises. It is a waste of time and effort to measure such specimens simply to verify what the eye so quickly discerned. Only the poorly differentiated pelvises will give an observer trouble and here he may find it necessary to check his visual impressions by measurements.

One of the advantages attributed by the authors to their method is that it provides an "explicit basis" for decisions on sex. The need for such a basis certainly should dictate the use of the method. I fear, however, that this advantage is offset by the limitations inherent in all measurements, namely, that they are poor descriptive agents and are subject to various kinds of error. As is all too well known to anthropometrists, an index tells nothing but the percental relationship of two linear dimensions; it tells nothing about the shapes of the parts included within the dimensions. This is

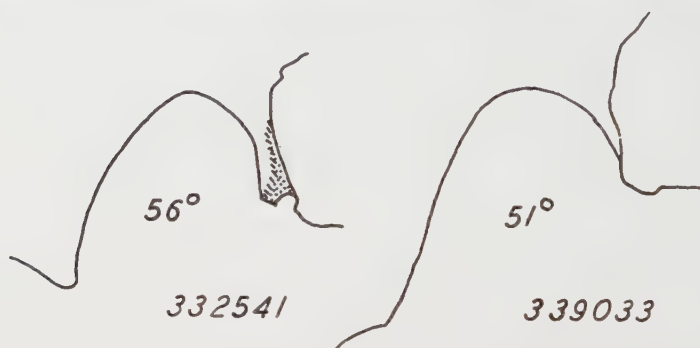


Fig. 1 Stereographic drawings of the sciatic notches of two Eskimo pelves of questionable sex, with measurements of angulation as obtained by R. E. Hanna (personal communication).

just as true of the ischium-pubis index as it is of the cranial index. Another illustration is provided by the sciatic notches of the two specimens of uncertain sex discussed above (fig. 1). Note the great differences in detail here, including a pre-auricular sulcus in one case and its absence in the other. Any attempt to describe these notches by angles or maximum widths misses many other things that the eye sees.

The matter of accuracy in measuring also is an important consideration so far as the authors' method is concerned. All of the landmarks used by them are ill-defined: The central point in the acetabulum, the point of ilio-pubic junction on the ilio-pectineal line, and the point on the iliac crest at the limit of attachment of the ilio-lumbar ligament. I doubt very

much that trained observers would agree on the location of these indefinite points in a good proportion of cases. A bias in measuring, growing out of mistaken concepts of landmarks, might affect the sexing of cases in the intermediate range.

The authors' method suffers also from vague definitions of procedures. Consider, for example: "The maximum width of the sciatic notch was measured" (Washburn, '49, p. 428). Is this width the diagonal line between the extremities of the notch? And if so, what does one do when one of these extremities is ill-defined? If one gives up this measurement and tries to express the notch in the form of an angle, is he much better off with the following definition? "The angle of the sciatic notch was determined by: placing the innominate bone, medial surface upward, on a piece of paper; tracing the shadow of the notch cast by a single, distant light; and drawing straight lines tangent to the sides of the notch" (Hanna and Washburn, '53, p. 22). Readers might try applying this definition to the diagrams in figure 1 to see whether they obtain the authors' assigned angles. Here again an incorrect expression of the form of the notch will affect the sexing.

Criticisms of this sort, although they involve points that undoubtedly will be clarified in time by the authors, are mentioned here simply to show that sexing of the pelvis by measurement is not something to be taught—as advertisements of commercial courses are wont to say—"in three easy lessons." Yet in spite of these deficiencies the method has great promise. What it needs is more study based on known material. I feel, therefore, that until the method is better perfected, the authors are making a mistake both in suggesting that it supplant traditional teaching and in applying it so rigidly to unknown material.

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HUMAN BODY SIZE AND CAPABILITIES IN THE DESIGN AND OPERATION OF VEHICULAR EQUIPMENT. By R. A. McFarland, A. Damon, H. W. Stoudt, A. L. Moseley, J. W. Dunlap and W. A. Hall.— This manual outlines the principles of human engineering to the design of all types of vehicular equipment, including armored vehicles and aircraft. Pertinent studies from the fields of applied physiology, psychology and anthropometry are reviewed and original data on the body size of commercial drivers are presented in percentile form with explanations for their application to problems of design. The purpose of the manual is to enable safety, engineering, and medical personnel to guide and evaluate the design of vehicles with respect to the man-machine integration as it affects the operator's safety, efficiency and health. The manual contains 180 pages of text, 60 tables, 45 illustrations and a bibliography of 117 items. Copies may be obtained from Dr. Ross A. McFarland, Harvard School of Public Health, 695 Huntington Avenue, Boston 15, Massachusetts.

THE BLOOD GROUPS IN PAKISTAN

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While the recipients of Fulbright awards in 1952 the authors were able to determine the A_1A_2BO , MNS, and Rh blood groups of a series of Pakistanis in the two cities of Lahore and Peshawar in West Pakistan, and in Dacca in East Pakistan. A few subjects in Lahore were tested also for Kell, Duffy and Kidd.

The subjects were from hospital wards, out-patient clinics, and university classes. No selection was exercised, but a record was made of the birthplace of each subject. Of those tested in Lahore 204 were natives of the Punjab province, and 24 were from other parts of Pakistan and India; of the 228 tested in Peshawar 153 were natives of Peshawar District and 75 were from other parts of the Northwest Frontier Province (NWFP); of the 266 tested in Dacca 236 were natives of Bengal and 30 were from other parts of Pakistan and India. No very striking differences between the natives and the other members of a series appear in any case, but the results on the natives are in each case presented separately. The results of our tests are shown in table 1, and the calculated gene frequencies in table 2.

The tests were carried out by the standard techniques (Schiff and Boyd, '42; Wiener, '43; Race and Sanger, '50). The M and N reagents and the anti-A and anti-B sera were powerful reagents prepared in our own laboratory (Boyd, '39a, '47). The anti-S, anti-Kell, anti-Kidd and anti-Duffy were the gift of Doctor Vogel and Doctor Rosenfield. The subgroups of A and AB were determined with a Lima bean extract prepared in our laboratory (Boyd and Reguera, '49). All the results obtained with this reagent were checked with

TABLE 1

Results of blood group determinations in Pakistan

	TOTAL LAHORE		PUNJABIS ALONE		PESHAWAR		OTHER NWFP		TOTAL DACCA		BENGALIS ALONE	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
O	75	32.89	68	33.33	46	29.68	19	25.33	93	34.96	82	34.75
A ₁	36	15.79	29	14.22	31	20.00	22	29.33	57	21.43	52	22.03
A ₂	7	3.07	7	3.43	9	5.81	2	2.67	8	3.01	6	2.54
A	6	2.63	6	2.94	0	0	1	1.33	0	0	0	0
ΣA	49	21.49	42	20.59	40	25.81	25	33.33	65	24.44	58	24.58
B	68	29.82	59	28.92	44	28.39	25	33.33	83	31.20	75	31.78
B _w	8	3.51	8	3.92	5	3.23	2	2.67	5	1.88	5	2.12
ΣB	76	33.33	67	32.84	49	31.61	27	36.00	88	33.08	80	33.90
A ₁ B	20	8.77	19	9.31	14	9.03	2	2.67	13	4.89	9	3.81
A ₂ B	3	1.32	3	1.47	5	3.23	2	2.67	7	2.63	7	2.97
AB	5	2.19	5	2.45	1	0.65	0	0	0	0	0	0
ΣAB	28	12.28	27	13.24	20	10.43	4	5.33	20	7.52	16	6.78
Σ	228		204		155		75		266		236	
M	36	15.93	35	17.33	18	11.76	8	10.67	40	15.38	35	15.22
MS	39	17.26	34	16.83	46	30.07	18	24.00	48	18.46	44	19.13
MN	50	22.13	44	21.78	28	18.86	15	20.00	59	22.69	47	20.43
MNS	59	26.11	53	26.24	45	29.41	21	28.00	67	25.77	62	26.96
N	23	10.18	19	9.41	11	7.19	6	8.00	22	8.46	21	9.13
NS	19	8.41	17	8.42	5	3.27	7	9.33	24	9.23	21	9.13
Σ	226		202		153		75		260		230	
CDe/C	88	38.77	75	36.95	62	40.00	18	24.00	131	49.25	118	50.00
CDe/c	67	29.52	64	31.53	38	24.52	25	33.33	65	24.44	58	24.58
cDE	15	6.61	12	5.91	12	7.74	7	9.33	13	4.89	12	5.08
CDE/c	28	12.33	24	11.82	16	10.32	12	16.00	30	11.28	24	10.17
cde	12	5.29	12	5.91	14	9.03	7	9.33	10	3.76	9	3.81
CDE/C	4	1.76	5	2.46	4	2.58	3	4.00	6	2.26	6	2.54
cDe	11	4.85	9	4.43	6	3.87	3	4.00	5	1.88	4	1.69
Cde/c	2	0.88	2	0.99	2	1.29	0	0	4	1.50	3	1.27
Cde/C	0	0	0	0	0	0	0	0	2	0.75	2	0.85
cdE	0	0	0	0	1	0.65	0	0	0	0	0	0
Σ	227		203		155		75		266		230	

The symbols A₁, A₂, A₁B, and A₂B designate the subgroups of A and AB. Symbol A means group A not assigned to subgroup, AB means group AB not assigned to subgroup. The symbol Σ indicates total. B_w indicates individuals reacting weakly with anti-B serum (see text). Rh types are given in terms of the reactions with the four sera anti-C, anti-D, anti-E, anti-c, in that order, except that the *symbol c* is not repeated in cases where anti-C reacted negatively. Thus CDe/C means bloods positive with anti-C and anti-D, and negative with anti-E and anti-c. Symbol cde indicates bloods negative with anti-C, anti-D, and anti-E and positive with anti-c (Rh negative bloods). "Total Lahore" means results for all persons tested in Lahore, "Punjabis alone" means those persons whose birthplace was the Punjab. "Peshawar" indicates results for persons born in Peshawar District. "Other NWFP," persons born in parts of the Northwest Frontier Province other than Peshawar District. "Total Dacca" includes all persons tested in Dacca, "Bengalis alone" those persons born in Bengal.

TABLE 2
Gene frequencies calculated from results of table 1

	PUNJABIS ALONE		PESHAWAR		OTHER NWFP	TOTAL Dacca	BENGALIS ALONE	
	(a)	(b)	(a)	(b)			(a)	(b)
TOTAL LAHORE								
P ₁	.15064	.14911	.16048	.16042	.19999	.15317	.13941	.14028
P ₂	.03348	.03865	.05476	.05480	.02182	.02319	.03287	.03310
q	.25961	.26173	.25292	.25294	.23942	.22086	.23086	.23090
r	.55615	.55427	.53184	.53184	.53824	.60272	.59684	.59570
χ ²	5.451	5.126	0.988	0.987			7.983	7.960
m _s	.38565	.41428	.32945	.33510	.33576	.39037	.37788	.38000
m _s	.18736	.16740	.32742	.27818	.25091	.19040	.20256	.20043
n _s	.30883	.30390	.28092	.32176	.28607	.28909	.29132	.28920
n _s	.11816	.11442	.06222	.06496	.12726	.13012	.12825	.13037
χ ²	1.596	0.815	1.065	1.010			0.531	0.517
R ₂	.09592	.0872	.0762	.08778	.12029	.07697	.0759	.07637
R ₀	.07918	.0725	.0489	.04774	.05766	.03934	.0353	.03875
R ₀	0	0	.0179	.00744	0	0	0	0
r	.20596	.2245	.25055	.25056	.29538	.17504	.1748	.17071
R ₂	.01360	.0195	.02026	.02173	.03907	.01982	.0174	.01628
R ₁	.58673	.5763	.57396	.55744	.48760	.65082	.6645	.63299
R ₁	.01862	.0199	.02155	.02728	0	.03801	.0320	.06489
χ ²	1.202	1.152	10.157	9.450			4.527	2.901

The symbols p₁, p₂, q, and r stand for the frequencies of the genes A₁, A₂, B, and O respectively. m_s, m_s, n_s and n_s stand for the frequencies of the M_s, M_s, N_s, and N_s genes respectively. R₂ stands for the cDe gene, R₀ for cDe, and R₁, R₂, R₁ and R₁ for the genes cDe, cDe, cDe, and cDe respectively. In case only one set of frequencies are given, they were calculated by an approximate method, when a second set is given, the second set was calculated by a maximum likelihood method (see text). Values of χ² are calculated from the expected numbers, as calculated from the gene frequencies, and the numbers actually observed.

an absorbed group B serum given us by Dr. A. S. Wiener. The anti-Rh reagents anti-C(anti-Rh'), anti-D(anti-Rh₀), anti-E(anti-Rh'') and anti-c(anti-hr') were purchased from the Wiener serum laboratories.

It will be observed that in a few cases we did not assign bloods of groups A or AB to subgroups. In most cases this was because we did not find opportunity to make the tests, but in a few cases the diagnosis proved difficult or doubtful. It is possible that some of these undiagnosed bloods belong to some further sub-type such as the A_{1,2} reported by Wiener ('43), but they were not further investigated, and in calculating the gene frequencies they have been arbitrarily assigned to the usual subgroups in the ratio found for the diagnosed A's and AB's, to the nearest whole number.

Although our anti-B reagent, prepared by injecting a group A donor with group B substance (Boyd, '47), had a titer of over 1:1000 and gave very powerful reactions with most B and AB bloods, in some cases it gave weaker reactions which, although definitely positive, were sharply distinguishable. We have not observed this phenomenon in tests made in this country. We lacked time to investigate whether these reactions corresponded to the hypothetical subgroups of B and AB which some workers have reported (Matta, '37). The groups of individuals which gave these weaker reactions are distinguished by the symbol B_w in table 1, but have been counted simply as B's in computing the gene frequencies.

The gene frequencies for the total Lahore and Dacca series, and for the 75 subjects from parts of the NWFP other than Peshawar District, have been calculated by recently devised methods which are however only approximate. [For the MNS and Rh the methods of Mourant ('53) were used.] Similar calculations were made for the other data, but in addition, for the Punjabis, Peshawaris and Bengalis maximum likelihood estimates of the gene frequencies for the MNS and Rh systems have been calculated, using the method of Fisher ('46, '47) for the Rh frequencies of the Bengalis and the method of Boyd ('54b) for the Punjabis

and Peshawaris. The gene frequencies for the A_1A_2BO system were calculated by two methods; the approximate method of Boyd ('54a), and the maximum likelihood of Stevens ('38).

The relative merits of these different methods of calculating gene frequencies have been discussed elsewhere (Boyd, '54a, '54b, '54c), but it may be worth while to observe that the new approximate methods, in contrast to the crude square root methods formerly in use, suffice in nearly every case to give estimates of the gene frequencies which do not differ from the maximum likelihood estimates by more than one standard error. It is thought that these new methods will be of considerable use to anthropologists.

The values of χ^2 (table 2) show the fit obtained when the frequencies expected from the estimated gene frequencies are compared with the observations. The fit is satisfactory in all cases except in the case of the Rh frequencies from Peshawar, where neither set of frequencies fits the observed data very well. We can offer no hypothesis to explain this.

COMPARISON OF OUR RESULTS WITH THOSE OF OTHERS

Our results for the Punjab and Peshawar show the very high frequencies for the gene B (0.25–0.26) discovered earlier for this region, which has one of the highest concentrations of this gene in the world. If we had this serological criterion alone, we might wish to class these populations as "Asiatic," but they are quite unlike the Chinese and Japanese in possessing the genes A_2 and $r(cde)$. The neighboring Punjabis and Peshawaris differ relatively little in their ABO and Rh frequencies (the R_0 gene may be somewhat commoner in the Punjab), but differ strikingly and significantly in the relative portions of M genes and N genes associated with S. In the Punjab the portion of the M genes associated with S is almost exactly the same (30.4%) as the portion of N genes associated with S(30.3%), but in Peshawar these numbers become 45.5 and 19.9% respectively. In this respect the inhabitants of the Punjab are unusual, as it is

customary to find a difference in the proportion of S-bearing M and N genes, and in Europe S is predominantly associated with M. In the Chenchu in southern India, Simmons et al. ('53) found a similar situation to that found by us in the Punjab; there S-bearing N genes slight predominated. It is interesting to reflect that if the anti-S serum had been discovered first in the Punjab, its relation to the MN system would not have been noticed.

It is not surprising that the population of Bengal, 1000 miles from West Pakistan, shows some differences in blood group gene frequencies. They are only partly in the direction of being more Asiatic, however. The frequencies of the A_2 and Rh negative genes are lower, as might have been expected, but at the same time the frequency of the B gene falls a little. Somewhat similar results have been found for India (Wiener, Sonn and Belkin, '45; Prasad, Ikin and Mourant, '49).

Chaudhri, Ikin, Mourant and Walby ('52), while the present authors were working in Pakistan, reported the results of their examination in London of the bloods of 101 natives of the Punjab and the NWFP. On the whole their results agree closely with ours. We did not possess anti-e or anti- C^w sera, and consequently could not have detected the rare genotypes cDE/CDE and C^w de/cde which these authors reported. We found low frequencies of two Rh genes, R_0 and R' , which were not found at all by Chaudhri et al., doubtless because of the small size of their sample.

Chaudhri et al. do not state how many of their subjects were natives of the Punjab and how many from the NWFP, but the relative numbers can be calculated approximately from the portions of the Ms, MS, Ns and NS genes they found, as their results are roughly intermediate between those found by us for the Punjab and Peshawar. If we assume that the lower frequency of the Ns gene reported by them is merely an accident of sampling, their results are compatible with the assumption that about half of their subjects were Punjabis and about half from the NWFP.

The results of our tests with Kell, Duffy and Kidd are on the whole more similar to those obtained by Miller, Rosenfield and Vogel ('51) for the White population of New York City than for the Negroes or Chinese, but there is a suggestion that the frequency of Duffy positives observed by us is greater than that found in the Whites or Negroes, but not

TABLE 3

Results of testing Punjabis (Lahore) with anti-Kell (K), anti-Kidd (J), and anti-Duffy (F)

REACTION	NO.	%	REACTION	NO.	%	REACTION	NO.	%
K +	14	16.09	J +	49	73.13	F +	52	76.47
K -	73	83.91	J -	18	26.87	F -	16	23.53
Σ	87	100.00	Σ	67	100.00	Σ	68	100.00

TABLE 4

Results of three series of determinations on Northwest Pakistan populations

AUTHOR	Chaudhri et al.	Boyd and Boyd	Khan
Origin of sample	Punjab and NWFP	Punjab	Punjab (+ some NWFP and Indian)
O	27.72	33.33	30.64
A	23.76	20.58	24.48
B	39.60	32.83	34.78
AB	8.91	13.23	10.10
Number tested	101	204	10,000
p	.1805	.1833	.1910
q	.2841	.2617	.2573
r	.5354	.5550	.5517

as high as that found in the Chinese. Chaudhri et al. report a still higher percentage of Duffy positives in the Pakistanis tested by them. The difference between their results and ours is nearly, but not quite, significant.

The results of ABO determinations of 10,000 individuals at the Blood Bank in Lahore have been reported by Kahn ('52). Table 4 shows a comparison of his results with ours

and those of Chaudhri et al. Application of the χ^2 test shows the differences are not significant.

Dr. M. Attabudin kindly communicated to us the results of his tests on 1000 persons in the Blood Bank in Dacca. He found $O = 33.80$, $A = 25.40$, $B = 31.10$, and $AB = 9.70$. It will be seen that our results for Dacca are in excellent agreement with this larger series.

DISCUSSION

On the whole our results confirm and extend what was already known of the genetical anthropology of the northern part of the Pakistan-India sub-continent. They serve to fix the frequency of the Rh negative gene ($r = cde$) in this part of the world as about 0.20–0.25, and establish the proportion of A_2 as about the same as in Europe ($A_2/A_1 = \text{ca. } 0.20$). Both of these "European" characters seem to fall off in East Pakistan ($r = 0.17$, $A_2/A_1 = 0.12$), although the results from this part of Pakistan are still definitely European in character.

The frequencies of B in our populations ($q = \text{ca. } 0.26$) are definitely higher than anything to be found in Europe, and indeed come close to the highest values in the world. Chaudhri et al. point out certain similarities between their results and those obtained in certain European populations, particularly in Sardinia, in regard to the frequencies of $R_1(CDe)$, $R_2(cDE)$, and $r(cde)$, and suggest a possible relationship, but they also mention that the ABO frequencies are quite different, and the high frequency of Duffy positives is different.

GENERAL REMARKS

The data available on the blood groups in India and Pakistan have been summarized in various places (Boyd, '39b; Sarkar, '36-'37, '42-'43, '49; Prasad et al., '49; Majumdar and Bahadur, '52; Chaudhri et al., '52; Simmons et al., '53). The situation is extremely complex, and the difficulty of interpreting the results is not lessened by the existence of the

caste system in India and the presence of aboriginal tribes which until recently were more or less isolated genetically from their neighbors. Nevertheless, some rough generalizations may be made. On the whole we may say that blood group A is frequent ($p = \text{ca. } 0.19$), B is quite high ($q = \text{ca. } 0.26$), subgroup A_2 is present, M tends to be high (values of 0.76 have been reported for small samples), about 60% of the population is S positive, Rh negatives are found ($r = \text{ca. } 0.25$), and gene R' is present.

It has been pointed out by Simmons et al. ('53) that several of these features (the presence of A_2 , the preponderance of M over N, the percentage of S positives, the presence of the genes r and R') are similar to those of white Caucasians. This suggests that in spite of the often deep skin pigmentation the Indians possess considerable amounts of a racial component common to them and the white Europeans. The prevalence of a typical "European" cast of features (Bowles, '54) and straight or slightly wavy hair furnish a more subjective support of this hypothesis, which applies not only to the northern and central parts of India where languages of Indo-European stock are spoken, but to large areas in the south where non-Indo-European languages are spoken.

The existence of this strong evidence of racial kinship between Indians and white Europeans supports the suggestion made by a number of authors (e.g. Boyd, '50) that skin color is a strongly adaptive character. There now seems little room for doubt that the degree of pigmentation has been increasing in India during the last tens of millenia. It has probably been decreasing in Europe during the same period.

The general serological resemblance of the Indian populations to the Europeans holds in spite of the fact that the frequencies of B in India and Pakistan are much higher, especially in the northern regions, than anything observed in Europe. It will be recalled that the frequency of the B gene increases as one travels from west to east in Europe, and reaches its highest European values in the European populations of the U.S.S.R. It was proposed by Candela ('42)

that the B in western Europe was brought in by the brachycephalic Asiatic armies which invaded Europe from the 5th to the 15th centuries, and it still seems possible that this accounts for a large part of the B in western Europe. However, the value of B in Iceland is too high to be readily accounted for on this hypothesis (cf. Ashman, '50), and local concentrations of B have been found in Wales (Mourant and Watkin, '52) which suggest the presence of a relatively large amount of B in those areas where the present population contains a Paleolithic foundation. We evidently have to allow for the early presence of considerable B in populations which, today at least, are fully European in other respects.

It does not seem likely to us that it will ever be satisfactory to classify the peoples of India and Pakistan as members of the European race. There are too many differences. At the same time, they clearly do not belong to the Asiatic race proposed by Boyd ('50). The situation may be, indeed doubtless is, too complex to allow the assignment of all the inhabitants of the sub-continent to any one race. Until further data are available, however, and for purposes of simplicity in classification, we should like to suggest that these peoples continue to be placed in an Indian or Indo-Dravidian race (cf. Hooton, '46), defined along the lines laid down above, which would be intermediate between the Asiatic race and the European race (Boyd, '50), but closer to the European.

Some anthropologists have postulated a relationship between populations of southern India and the Australian aborigines (Hooton, '46). It is true that Lehmann and Cutbush ('52a, '52b) found the gene R_z , which is relatively frequent in the Australian aborigines (Simmons and Graydon, '48; Sanger, Walsh and Kay, '51) to have a frequency of 0.04 in south Indian Veddoids. In all other respects, however, the serological evidence does not lend much support to the supposition of a relationship between the two peoples. We need only mention that B is very high in India and absent in Australia; S is frequent and A_2 present in India, whereas both are absent in Australia; the frequency of N is very

high in Australia and moderate to low in India. As for R_z , we found (present study) a frequency of ca. 0.02 in the Punjab and in Peshawar District, and not much less in Bengal, so this gene is not peculiar to southern India. In addition, it has been found recently (Horsfall and Lehmann, '53) that the sickle cell trait, present in the Veddoids, is absent in the Australians. Any relationship between the Indians and the Australian aborigines can therefore hardly be more than the "slender" one allowed by Simmons et al. ('53). These authors point out that no Pacific population possesses an array of blood characters similar to that found in India.

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SUMMARY

Blood grouping data for the A_1A_2BO , MNS and Rh systems are reported for three localities in Pakistan (Lahore, Peshawar, and Dacca), and the results discussed in comparison with the results of previous work in the area. The general problem of the racial affinities of the populations of the Pakistan-Indian sub-continent is discussed, and it is proposed

to classify these populations for the time being as members of an Indian or Indo-Dravidian race, intermediate between European and Asiatic, but closer to the European.

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ANTHROPOLOGIE ET GROUPES SANGUINS DES POPULATIONS DU MAROC. By N. Kossovitch. xxix + 487 pp. Masson et Cie, Paris, 1953.—A limited anthropometry of some 60 sub-groups of the Moroccan population together with their ABO blood group frequencies are all combined to give a description of the total population of modern Morocco. The total sample of 5,309 individuals were measured—mostly head and face—and observations of eye and hair color plus simple ABO determinations complete the data. Attempts to show correlations between blood type and measurements, indices or observations are made but not demonstrated. The most unusual aspect of this work is the division of the total sample data into the many cultural sub-groupings.—F. P. Thieme.

OBESSE MOTHERS.—Data on weight, skeletal size, and period of gestation of neonates of obese women included in an experimental investigation on effects of nutrient supplements during pregnancy which was conducted at Pennsylvania Hospital in Philadelphia from 1947 to 1952 are presented in an article by Dorothy G. Wiehl and Winslow T. Tompkins, M.D., entitled "Size of Babies of Obese Mothers Receiving Nutrient Supplements." It is shown that women who are obese at the beginning of pregnancy tend to have heavier and longer babies than women who are of approximately normal weight. No correlation is found between prenatal gain in weight by the obese mothers and the size of their babies.

The obese women whose diets were supplemented with a protein concentrate had fewer babies of less than 38 weeks' gestation and less than 6.0 lbs. at birth than women who received a multiple vitamin supplement or no supplement. If both the protein concentrate and vitamins were taken during pregnancy, weight at birth relative to skeletal size is increased somewhat and suggests better general development of the baby.—Dorothy G. Wiehl and Winslow T. Tompkins, 1954 Size of babies of obese mothers receiving nutrient supplements. *Milbank Memorial Fund Quarterly*, 32: 125-140.

A BLOOD GROUP GENETICAL SURVEY IN THAIS, BANGKOK ¹

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The most recent investigation on the blood groups of the people of Bangkok, Thailand, was that of Phansomboon, Ikin and Mourant ('49), who reported the A-B-O, M-N and Rh frequencies for 213 individuals. The tests were somewhat limited due to the specimens having deteriorated slightly in transit from Bangkok to London, and as a result the findings with anti-A₁ and anti-e were said to be not entirely satisfactory. In the present survey carried out on 100 selected individuals with unmixed Thai parents, the following testing sera were employed: Anti-A, A₁, B, A + B, M, N, S, Rh₀ (D), rh' (C), rh^w (C^w), rh'' (E), hr' (c), hr'' (e), P, Le^a, Fy^a, and K.

The blood samples were collected in Bangkok by one of us (S.S.) and were tested about one week later in Melbourne. The methods employed for collecting and testing the blood samples have been described again in detail by Simmons, Graydon, Semple and Taylor ('51). The 100 blood samples were tested for each of 7 blood group systems; thus new data are provided for the subgroups of A, the S subdivision of M-N, and the blood groups P, Le^a, Fy^a and K.

¹ The authors acknowledge with gratitude a grant from the Wenner-Gren Foundation for Anthropological Research, Inc., part of which in this instance was used to pay air-freight charges for the transport of blood samples in ice, between Bangkok and Melbourne.

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RESULTS AND DISCUSSION

The A-B-O groups and subgroups. In the 100 samples tested, group O = 33%, group A₁ = 24%, group B = 35% and group A₁B = 8%. The calculated gene frequencies are $A = .180$, $B = .249$, $O = .571$. Twenty-four samples of group A and 8 of group AB were of subgroups A₁ and A₁B respectively.

The M-N types and S subdivisions. Type M was found in 44%, type MN in 42% and type N in 14%. The calculated gene frequencies are $m = .65$ and $n = .35$. In tests with anti-S 14% were positive. The S distribution was as follows: Type MS 6/44, type MNS 5/42 and type NS 3/14. The calculated gene frequencies are $ms = .595$, $mS = .045$, $ns = .320$, $nS = .040$.

The Rh types. In the series 68% were of type Rh₁Rh₁, 9% were Rh₁Rh₀, 3% were Rh₂Rh₂ and 20% were Rh₁Rh₂. The calculated gene frequencies are $R^1 = .820$, $R^2 = .130$, $R^0 = .050$. No rh^w (C^w) was detected in the series.

The P blood group. Using a potent example of anti-P recently found in Melbourne, 30% of the samples were P positive. The tests were read after one hour at 5°C. The results are regarded as being entirely reliable.

The Lewis (Le^a) group. Tests for this blood group were read after 15 minutes at 20°C. The test serum employed was a good example of anti-Le^a which had been made quite specific by absorption. Of the 100 blood samples tested 23% were Le(a+).

The Duffy (Fy^a) group. The tests for this group were made using an agglutinating anti-Fy^a serum kindly sent to us by Dr. D. Lehane of Liverpool, England. The tests were read after one to three hours at 20°C. Negative or weak-reacting cells were checked using a blocking anti-Fy^a serum generously supplied by Dr. A. S. Wiener, New York, followed by the anti-globulin test of Coombs. It was found that 98% of the specimens were Fy(a+). In using the agglutinating anti-Fy^a serum a dosage effect was observed as has been described by Race, Sanger and Lehane ('53).

The Kell (K) group. Preliminary tests for the K antigen were made using an agglutinating anti-K serum sent to us by

the Red Cross Blood Transfusion Service, Brisbane, Australia. This agglutinating anti-Kell serum had originally been detected by Dr. C. A. Holman of the Lewisham Hospital, London, when this blood donor resided in England. The Kell agglutinating antibodies like those of anti-Duffy referred to above were such that after absorption, the sera were used preferably without further dilution. Both sera in our hands gave their best reactions at 20°C. As all of the 100 blood samples failed to agglutinate with anti-K, they were also tested by means of the antiglobulin technique, and again, no evidence of the K antigen was detected.

P.T.C. tests. Of 56 army personnel tested, 53 (94.6%) were recorded as tasters. The high percentage of tasters is a characteristic of the Mongoloid people. Taste reactions in human populations have been tabulated by Montagu ('51), page 271.

It was stated earlier that the blood samples were collected from 100 individuals in Bangkok. A selection was attempted in view of the fact that preliminary enquiries showed that people thought to be "pure" Thai were of mixed blood, and admixture with Chinese was quite common. In view of this, comparisons are made between the gene frequencies found for Thais with those previously published for southern Chinese in 7 blood group systems. These comparisons are shown in tables 1 and 2. There is obviously great similarity between the frequencies for Thais and those for southern Chinese. No example of subgroup A_2 was found in either people. The Thais have a higher B than southern Chinese, and the frequency B .257 places the Thais with Indians .261, Chenchu of south India .275 (Simmons, Graydon, Semple and D'Sena, '53) and Ainu of Hokkaido .212 (Simmons, Graydon, Semple and Kodama, '53) amongst those groups with the highest frequencies of B found to date. The m frequency for Thais .65 agrees closely with the .662 reported by Phansomboon et al., and suggests that the m frequency in Thais (table 1) may actually be slightly higher than in southern Chinese. Frequencies of m of the same order have been found in Indonesians (Java) and Indians

TABLE 1
Gene frequencies for Thais and Chinese

POPULATION	AUTHORS	NUMBER TESTED	GENE FREQUENCIES									
			A	B	O	m	n	R ⁰	R ¹	R ²	R ³	r
Thais Bangkok	Present survey	100	.180	.249	.571	.650	.350	.050	.820	.130	0	0
Thais Bangkok	Piansomboon et al. ('49)	213	.148	.257	.595	.662	.338	.111	.756	.112	.022	0
Thais Bangkok	Niyomsen ('45)	6267	.161	.231	.608	...	...	...	...	...	...	...
Chinese Southern	Wiener et al. ('44)	138	.234	.202	.558	.551	.449	.004	.770	.207	0	.019
Chinese Southern	Simmons et al. ('50)	250	.168	.141	.692	.630	.370	.040	.760	.195	.005	0
Chinese ¹ Southern	Miller et al. ('50) and ('51)	293	.195	.162	.643	.607	.393	.029	.691	.197	0	.083

¹ The A-B-O, M-N-S and Rh gene frequencies (tables 1 and 2) have been calculated by the present authors from data published by Miller et al. ('50) and ('51). The M-N frequencies are for 103 individuals only.

TABLE 2
Other comparisons for Thais and Chinese

POPULATION	AUTHORS	NUMBER TESTED	S POSITIVE	ms	mS	ns	nS	P	LEWIS (Le ^a)	UFFY (Fy ^a)	KEEL (K)
Thais Bangkok	Present survey	100	14.0%	.595	.045	.320	.040	30%	23%	98%	0
Chinese Southern	Miller et al. '51)	103-85	10.7%	.574	.033	.382	.011	27.2% ¹	23.5%	99%	0

¹ In a previous survey Miller et al. ('50) found 32.6% of 190 southern Chinese residents in New York to be P positive.

(Moslems). These are the highest in south-eastern Asia and the western Pacific and amongst the highest in the world.

The gene frequencies for B , m and R^1 for the above areas have been tabulated by Simmons and Graydon ('51). The S antigen has been demonstrated in 14% of Thai samples and in 10.7% of Chinese. The M-N-S frequencies are shown in table 2 and the figures for Thais and Chinese are almost identical.

The Rh frequencies for both peoples are very similar. However, the gene R^2 reported in Thais by Phansomboon et al. ('49) was not detected in the present survey while the frequency of R^1 is slightly higher than for Chinese.

The comparisons in 4 other blood group systems P, Le^a , Fy^a and K show almost identical results for Thais and Chinese.

SUMMARY

Blood samples from 100 selected Thai individuals living in Bangkok have been tested for the blood groups A_1 - A_2 -B-O, M-N-S, Rh, P, Le^a , Fy^a and K, thus providing some new genetic data. P.T.C. taste tests were also carried out.

The gene frequencies have been compared with those for southern Chinese, and although the Thais have slightly higher frequencies for B , m and R^1 , the similarity in the 7 blood group systems indicates a close genetic relationship between the two peoples.

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AN Rh-Hr SYLLABUS. THE TYPES AND THEIR APPLICATIONS. By Alexander S. Wiener. xii + 82 pp. Grune and Stratton, New York, 1954. \$3.75.—This short book presents recent knowledge of the Rh-Hr blood types and closely related subjects in a compact glossary form with the material arranged in logical order. To the advanced student seeking detailed explanations of all of the facets of Rh typing or laboratory procedures, this is merely an appetizer. Yet the complex interrelationship of all the parts of the present picture of "Rh" is outlined and the latest information included. This syllabus together with the memorandum publication of Mollison, Mourant and Race ("The Rh Blood Groups and their Clinical Effects." Med. Res. Council, Memo. no. 27, 1952. H.M. Stationary Office, London) should be primary guides to students seeking understanding of the labyrinth of actions and interactions which presently characterize the procedures related to Rh laboratory work.—F. P. Thieme.

A STUDY OF THE HEREDITARY BLOOD FACTORS AMONG THE CHIPPEWA INDIANS OF MINNESOTA

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Perhaps no ethnic group has received more study from the standpoint of distribution of the blood groups and other hereditary antigenic factors in human blood than have the Indians of North and Central America. To a lesser extent this holds true also for studies of the Eskimos and of the Indians of South America. This interest was accelerated largely by the early and repeatedly confirmed observations that a high incidence of group O exists among American Indians, and later by the finding of a high incidence of group A (exclusively subgroup A_1) among the Blood, Blackfeet and related tribes (Matson and Schrader, '33). These observations perhaps suggest at least two separate migrations of Amerinds into this hemisphere, each group being originally either a pure group O or group A people. An alternative explanation is the loss of genes B and/or A in small isolates after a few generations (genetic drift).

The unusually high incidence of the M factor in both groups of American Indians as compared to Whites and other races likewise has been a noteworthy observation. The incidence of the Rh positive types among American Indians and Eskimos has been uniformly observed to be extremely high and agrees with similar high incidence of the Rh factor among other non-European peoples, e.g., Chinese, Indonesians, and aborigines of Australia and the Pacific Islands. A compre-

hensive review of this subject is given by Boyd ('50) and more recently by Mourant ('54).

Although numerous investigators have studied Amerinds for their distribution of hereditary blood factors of the ABO, MN, and Rh-Irr systems, the frequencies of the newer blood factors have until recently not been reported. Reference will be made below to three very recent studies of the newer blood factors among several Indian tribes living in three different geographic areas.

EXPERIMENTAL

Through the cooperation of the Department of Indian Affairs, an opportunity was afforded in the spring of 1952 to investigate the distribution of the hereditary antigens among the Chippewa Indians of northern Minnesota. Blood was obtained from these Indians in the several communities of Cass Lake, Red Lake, and Ponemah. Duplicate specimens of bloods were collected by deep finger puncture. Several drops of blood were allowed to fall into each of two dry, chemically clean serological tubes about 10 mm in diameter properly labelled by number. One of the specimens of clotted blood from each individual was sent via special air-express to the Blood Grouping and Rh Laboratory of the Minneapolis War Memorial Blood Bank and the other sent by special air-express to Ortho Research Foundation, Raritan, New Jersey. The samples arrived at the laboratories in good condition and were immediately transferred to a refrigerator. Tests for A, B, M, N, S, D, C, E, c, K (Kell), and Fy^a (Duffy) were done in each laboratory with suitable anti-sera, after which results were compared, evaluated, and interpreted. Tests for s and k were carried out at Raritan alone and those for P at Minneapolis alone. The results were controlled by a simultaneous study of 300 white individuals obtained in Minnesota and tested with the same reagents in Minneapolis. These bloods, however, were not sent to Raritan. The gene frequencies for the M-N, S-s, and K-k systems are given in terms of the homozygotes plus one-half of the heterozygotes.

In the absence of anti-Fy^b, the gene frequencies for Fy^a were derived by the square-root method.

RESULTS AND DISCUSSION

In this study the Agency records were relied upon for the degree of blood purity among these Indians. It was recognized, however, that the information obtained from the Agency records, at least in some cases, left something to be desired with respect to reliability of the data concerning the degree of admixture with other racial groups. Not infrequently did

TABLE 1
The ABO system

	NO.	PER CENT OF GROUP				GENE FREQUENCIES		
		O	A	B	AB	O	A	B
Chippewa								
Pure	161	87.6	12.4	0.0	0.0	.936	.064	.000
> $\frac{3}{4}$	128	75.0	24.2	0.8	0.0	.865	.130	.005
< $\frac{3}{4}$	206	62.1	32.5	4.4	1.0	.770	.193	.037
Minnesota Whites	300	40.0	45.7	11.7	2.6	.625	.290	.085

it happen that an Indian whose appearance betrayed white admixture was recorded as a full-blood. Admixture, furthermore, is known to exist between various tribes of Indians.

The results of the tests on the blood specimens are arranged in the several tables according to the degree of Indian blood as given in the Agency records, i.e. (1) putative full-bloods, (2) mixed bloods having three-fourths or more Indian blood, and (3) mixed bloods having less than three-fourths Indian blood. In the several tables, the three groups are listed as "pure," "> $\frac{3}{4}$," and "< $\frac{3}{4}$," respectively. Subjects with less than one-fourth Indian blood were not included.

ABO blood groups. In all, 495 blood specimens of Indian blood were tested for the ABO groups, the results of which are shown in table 1.

From the table it will be noted that the Chippewa Indians are predominantly a group O people, the putatively pure bloods showing a gene frequency of O as high as 93.6%. This is in agreement with the findings among other American Indian tribes, with the exception of the Blackfeet and Blood tribes who have gene frequencies of about 40 and 60% for O and A, respectively. No individuals of groups B or AB were found among the putatively full-blooded Chippewas.

It was further noted that there was a progressive decrease of group O and an increase of groups A and B as the degree of Indian blood decreases and caucasoid blood, mainly French and English, is introduced into the race. In the group having more than three-fourths Indian blood, an incidence of 75% group O was found, in contrast to 62.1% in those having less than three-fourths Indian blood, corresponding to gene frequencies of 86.5 and 77.0%, respectively.

The frequencies of the ABO genes in the control Minnesota series which is heavily sprinkled with Scandinavian stock show a lower O and higher A than is to be expected in a more representative group of caucasoids living in the United States. There is, however, very close agreement with the values of Wolff and Jonsson ('35) for a native Swedish population, i.e. 60.6, 30.5, and 8%, respectively, for genes O, A, and B.

The MN-Ss system. The pure Chippewas showed the expected high M gene frequency but a higher value of 80% was recently reported by Chown and Lewis ('53) for the Blood tribe, and Boyd ('50) lists 91% for Navaho Indians and Eskimos of east Greenland. Gene frequencies of 76 and 71%, respectively, were reported by Pantin and Kallsen ('53) in Diegueño Indians of southern California and by Hannah et al. ('53) in Pima Indians of Arizona.

However, the dilution effect so clearly shown with tests of the ABO groups, and the Rh-Hr, K-k, and Fy^a factors described below was not evident for genes M and N. Actually, the "< $\frac{3}{4}$ " group had 45% M genes in contrast to 51% for the "> $\frac{3}{4}$ " group (table 2).

These findings were controlled by tests of the Minnesota Whites who in view of their Scandinavian ancestry had 59.5% *M* genes, somewhat higher than the 55% for the average U. S. or English population, but corresponding very closely to the value of 59.6% reported by Wolff and Jonsson ('35) for Swedish natives.

The possibility of technical error seems to be excluded since the anti-*M* and anti-*N* reagents employed gave maximum reactions and so far as the three groups of Indians are concerned, identical results were obtained in tests done at Minneapolis and Raritan. An alternative explanation for the failure to demonstrate a dilution effect is chance variation in the

TABLE 2
The M-N system

	NO.	PERCENTAGE FREQUENCIES			GENE FREQUENCIES	
		<i>M</i>	<i>MN</i>	<i>N</i>	<i>M</i>	<i>N</i>
Chippewa						
Pure	161	52.8	38.0	9.2	.718	.282
> $\frac{3}{4}$	128	28.1	45.3	26.6	.508	.492
< $\frac{3}{4}$	206	28.6	52.9	18.5	.551	.449
Minnesota Whites	300	35.00	49.7	15.3	.599	.401

128 individuals of the "> $\frac{3}{4}$ " group of Indians. This view seems to gain support from the results of tests for the *S*-s factors which are genetically linked with *M-N*.

The three groups of Chippewa Indians have a gene frequency of *S* varying from 33.7 to 40.2% — values which do not differ much from 38.2% reported by Chown and Lewis ('53) for the Blood tribe. As in the *MN* tests, the "> $\frac{3}{4}$ " group also shows an irregularity — in this case, the highest value in the three groups for gene *S*. Calculation of gene *S* by the square root method gives values of 0.93, 1.05, and .90 for the three groups of Chippewa Indians, respectively, as compared with 1.03, 1.04, and 0.96 for gene *M* derived by the same method. The somewhat greater deviation of *S* genes

from 1.00 as compared to *M* genes possibly points to a lack of internal consistency perhaps attributable to improperly standardized reagents for the S-s factors. Control tests of both anti-S and anti-s sera with standard bloods of all groups, however, gave satisfactory results. The Minnesota Whites

TABLE 3
The S-s system

	NO.	PERCENTAGE FREQUENCIES			GENE FREQUENCIES	
		<i>SS</i>	<i>Ss</i>	<i>ss</i>	<i>S</i>	<i>s</i>
Chippewa						
Pure	161	8.7	50.9	40.4	.342	.658
> $\frac{3}{4}$	128	18.7	43.0	38.3	.402	.598
< $\frac{3}{4}$	206	7.3	52.9	39.8	.338	.662
Minnesota Whites	240	48.8 ¹		51.2	.290	.710

¹ These bloods were tested only with anti-S.

TABLE 4
The M-N-S-s system

	NO.	PERCENTAGE FREQUENCIES								
		<i>M</i>			<i>MN</i>			<i>N</i>		
		<i>SS</i>	<i>Ss</i>	<i>ss</i>	<i>SS</i>	<i>Ss</i>	<i>ss</i>	<i>SS</i>	<i>Ss</i>	<i>ss</i>
Chippewa										
Pure	161	7.5	31.7	14.3	0.6	16.1	20.5	0.6	3.1	5.6
> $\frac{3}{4}$	128	7.0	14.1	7.0	7.9	23.4	14.1	3.9	5.5	17.2
< $\frac{3}{4}$	206	3.9	16.0	8.3	2.9	30.6	19.9	0.5	6.3	11.6
Minnesota Whites	240	22.1 ¹		11.3	22.9 ¹		28.3	3.8 ¹		11.6

¹ These bloods were tested only with anti-S, so that the three values indicated by ¹ include genotypes *SS* and *Ss*.

tested in Minneapolis with a different anti-S reagent showed a gene frequency of 29.1% for *S*, which does not differ much from 33.7 and 34.9%, respectively, for Englishmen (Race and Sanger, '50) and a White population in the United States (Levine et al., '51). The frequency of *S* in native Swedes has not yet been reported.

The distribution of the S-s antigen in relation to the three genotypes *MM*, *MN*, and *NN* is given in table 4. From these data the frequency of the 4 chromosomes *MS*, *Ms*, *NS*, and *Ns* were derived by Professor Howard Levene and Mr. William Pollitzer, Columbia University, and these are given in table 5 along with the results for the Blood and Diegueño Indians studied recently and those of Race and Sanger ('50) for an English population. On comparing the results of the pure Chippewa and Blood tribes, *MS* and *NS* are in fair

TABLE 5
The MN-Ss chromosome frequencies
Based on data in table 4

	MS	Ms	NS	Ns
Chippewa				
Pure	.296	.424	.046	.234
> $\frac{3}{4}$	.264	.244	.138	.354
< $\frac{3}{4}$	.253	.296	.084	.367
Blood ¹	.301	.565	.069	.065
Diegueño ²	.401	.355	.000	.244
English ³	.247	.283	.080	.390

¹ Chown and Lewis ('53).

² Pantin and Kallsen ('53).

³ Race and Sanger ('50).

agreement but *Ns* is considerably more frequent in the Chippewas at the expense of *MS*, which has a greater incidence in the Blood tribe. Further studies are required to determine whether the differences in *Ms* and *Ns* chromosome frequencies in the two tribes are significant and perhaps associated with the higher frequency of M in the Blood tribe. It is of interest that in the pure Chippewa and the Diegueños with *M* frequencies of 72 and 76%, respectively, the results shown in table 5 indicate a fair agreement in the MN-Ss chromosomes if the findings based on 39 specimens can be shown to be representative of the Diegueños as a group.

The Rh-Hr system. The results of tests with 4 sera, anti-D, anti-C, anti-E, and anti-c are presented in table 6. The anti-c

serum employed was produced by transplacental isoimmunization and was free from anti-E, as shown by absence of the E factor in the husband's blood. Furthermore, the anti-e serum failed to react with bloods of probable genotype R^1R^z (Ce/DCE). Only a limited number of bloods were tested with anti-e and these reactions are not represented in the

TABLE 6
The Rh system

		PPERCENTAGE FREQUENCIES								
no.		R ¹ R ¹	R ¹ r	R ² ?	R ¹ R ²	R ² R ¹	R ^o ?	r'r	r''r	rr
		DCe	DCe	DcE	DcE	DCE	Dce	dCe	dcE	dce
		DCe	dce	?	DC?	DC?	?ce	dce	dce	dce
<hr/>										
Chippewa										
Pure	161	9.9	7.5	39.1	41.6	1.3	0	0	0.6	0
> $\frac{3}{4}$	128	14.8	15.6	34.4	32.0	0.8	1.6	0	0	0.8
< $\frac{3}{4}$	206	17.5	17.5	27.2	32.5	2.4	1.0	0	0	2.0
<hr/>										
Minnesota Whites	300	15.3	39.6	11.0	13.7	0.3	4.7	0.7	0	14.7

TABLE 7
The Rh system

	CHROMOSOME FREQUENCIES						
	R^1	R^2	R^o	R^z	r'	r''	r
Chippewa							
Pure	.315	.587	.000	.019	.000	.079	.000
$> \frac{3}{4}$	.385	.452	.065	.010	.000	.000	.088
$< \frac{3}{4}$	.417	.384	.031	.029	.000	.000	.139
Minnesota Whites	.383	.169	.056	.000	.010	.000	.383

tables 6 and 7. The chromosome frequencies were computed according to the simplified method of Race and Sanger ('50).

All three groups show chromosome frequencies which are strikingly different from whites. A high R^2 , absence of low r , presence of r'' and R^z are characteristic of the Chippewa as well as the Blood tribe studied by Chown and Lewis ('53). Low r and high R^2 were reported also by Wiener et al. ('45)

for Mexican Indians, Matson and Piper ('47) for the Ute tribe, Matson and Roberts ('49) for Eskimos in western Alaska, and for the Diegueño and Pima Indians referred to above.

The three classes of Chippewa show a dilution effect roughly corresponding to the degree of purity as indicated by the frequencies of chromosome r , R^2 , and R^1 . Curiously enough, chromosome r'' , with a value of almost 8% in the pure Chippewas is not represented in the other two groups. No dilution effect can be demonstrated in chromosome R^2 but its presence in each of the three groups was to be expected in view of their high values of both R^2 and R^1 .

Chromosome R^0 , which was not found in the pure Chippewa, is unusually high in the " $> \frac{3}{4}$ " group and has twice the frequency of R^0 in the more diluted " $< \frac{3}{4}$ " group. According to information received from the officials of the agency, there is no evidence of admixture with Negroes, who have the world's highest R^0 , i.e. from 48–90%. Aside from a somewhat higher R^0 and a slightly raised R^2 , the chromosome frequencies in the control group of Minnesota Whites differ but little, if at all, from those found in western Europe.

The frequencies of the chromosomes in the pure Chippewa (this study) and the Blood tribe studied by Chown and Lewis ('53) are given below in terms of percentages.

	CHIPPEWA		BLOOD	
R^1	31.5	} 92.1	46.9	} 90.8
R^2	58.7		40.1	
R^0	0		0	
R^2	1.9		3.8	
r'	0	} 7.9	0	} 9.2
r''	7.9		2.7	
r	0		6.5	

Tested with anti-D alone, the pure Chippewa differs only slightly from the Bloods. Possibly, the difference of 1.3% is a reflection of the estimated one-sixth white admixture with the Blood tribe, but, in any event, a lower gene r (in terms

of tests with anti-D only) is to be expected in the pure Chippewa as shown in table 7. Again, as expected, high R^2 in both tribes is accompanied by moderate values of r'' , which is rare in all populations characterized by chromosome frequencies of 15% of R^2 or lower. The higher R^2 in the pure Chippewa than in Bloods appears to be significant and if this observation can be confirmed, then the two tribes may be differentiated in terms of R^2 as well as by the presence of r in the Bloods.

The P system. Tests for P were carried out only in Minneapolis with two of the three groups of Indians and the control series of local Whites. A suitable anti-P serum was not available at the Raritan laboratory. An antibody, anti-p,

TABLE 8
The P system

	NO.	PHENOTYPE PER CENT	
		P+	P-
Chippewa, pure	161	84.5	15.5
Chippewa, $> \frac{1}{4}$	128	83.0	17.0
Minnesota Whites	300	79.7	20.3

specific for the genetic allele of P does not exist. In general, tests with anti-P reagents, whether derived from human, normal, or animal serum, are difficult to read because a variable number of bloods give rather poorly defined reactions. Negroes have the highest incidence of P while Chinese have the lowest, with values of 97 and 31% respectively (cf. Miller et al., '51).

The findings in the two groups of Chippewa Indians, 84.5 and 83.0% positive bloods, are only slightly higher than in the control series of Whites (table 8). Because of the peculiarities of anti-P sera, these results are given in terms of phenotypes only. Chown and Lewis ('53) reported 85% positive P bloods among the Blood tribe, but Pantin and Janqueira ('52) found only 41.1% among 73 Brazilian Indians,

and Pantin and Kallsen ('53) report 57% positive reactions in 58 Diegueños.

The Kell-Cellano (K-k) system. Both anti-K and anti-k were employed for the Chippewa Indians in Raritan, while at the Minneapolis laboratory the three classes of Indians and the Whites were tested only with anti-K. The findings in the Chippewa in general and the Whites do not reveal any significant differences (table 9). The only individual of genotype *KK* was found among the " $< \frac{3}{4}$ " group.

TABLE 9
The K-k system

NO.	GENOTYPE FREQUENCIES			GENE FREQUENCIES	
	<i>KK</i>	<i>Kk</i>	<i>kk</i>	<i>K</i>	<i>k</i>
Chippewa					
Pure	161	0.0	14.9	85.1	.075 .925
$> \frac{3}{4}$	128	0.0	10.2	89.8	.051 .949
$< \frac{3}{4}$	206	0.5	7.3	92.2	.042 .958
Minnesota Whites	300	11.0 ¹	89.0	.057 .943	

¹ Not tested with anti-k. The value of 11% includes genotypes *KK* and *Kk*.

These findings differ from those reported by Chown and Lewis ('53) who reported their Blood and Blackfeet Indians to be homozygous and of genotype *kk*. Brazilian Indians, however, have as high as 12.8% of gene *K* in contrast to about 4.5% for a European population.

The Duffy (Fy^a) system. Only anti-Fy^a was available for testing the three series of Indians and the control group of Whites. The gene frequencies in the Chippewa show a remarkable dilution effect which appears to be directly related to the degree of admixture as given in the agency records (table 10). The value of 43.4% *Fy^a* genes in the control group agrees quite closely with 40.9% for a western European population.

Chown and Lewis ('53) reported a figure of 82% Fy^a genes in the Blood tribe. Other populations with high percentages of Fy^a genes are Chinese, Lapps, and natives of northwest Pakistan, with values of 90, 82, and 70 respectively. Negroes living in the United States have a low gene frequency of 14.8%. The contrasting results in the Chinese and Negroes were reported by Miller et al. ('51), and the data on the Lapps and natives of Pakistan were published by Allison et al. ('52) and Cutbush and Mollison ('50), respectively.

TABLE 10
Distribution of the Duffy (Fy^a) antigen among Chippewa Indians

	NO.	PHENOTYPE PER CENT		GENE FREQUENCY	
		Fy^a +	Fy^a -	Fy^a	Fy^b
Chippewa					
Pure	161	98.2	1.8	.867	.133
> $\frac{3}{4}$	128	92.6	7.4	.724	.276
< $\frac{3}{4}$	206	81.7	18.3	.572	.428
Minnesota Whites	300	68.0	32.0	.434	.566

In testing 73 Brazilian Indians, however, Pantin and Janqueria ('52) found all lacking Fy^a , the population thus being homozygous for Fy^b . The activity of their anti- Fy^a was controlled since it gave the expected incidence of positive reactions with White bloods. This remarkable differentiation of American Indians, if confirmed and established by tests with the rare anti- Fy^b , may be just as significant as the finding of a high A among Blood, Blackfeet, and related tribes. It seems advisable to delay speculation as to genetic drift or separate migration until these and neighboring Brazilian tribes are more thoroughly investigated.

SUMMARY

The separation of three classes of Chippewa Indians on the basis of degree of purity appears to be justified in a

study of their gene frequencies. Tests with reagents for the O, A, B, Rh-Hr, and particularly the Fy^a factor, indicate a dilution effect in their gene frequencies which conforms with the data in the agency records. To a lesser degree, this applies for the MN system, but a dilution effect could not be demonstrated in the tests for S-s.

Aside from the characteristic differences in genes *O* and *A*, the data for the other genes, on the whole, do not differ much from those reported for the Blood and Blackfeet tribes of Southwest Canada. Nevertheless, the pure Chippewa can also be differentiated from the Blood tribe by their higher R^2 , absence of *r*, and higher Fy^a . The discrepancies in the MN-Ss system in the Chippewa and Blood tribes may perhaps be an expression of the higher *M* gene in the Blood tribe.

The most characteristic feature of all American Indians tested is the highest frequency of R^2 of any population group in the entire world.

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Rh-Hr BLOOD TYPES. APPLICATIONS IN CLINICAL AND LEGAL MEDICINE AND ANTHROPOLOGY. By Alexander S. Wiener. xii + 763 pp. Grune and Stratton, New York, 1954. \$11.50.— This is a volume largely made up of selected articles in immunohematology from the 333 listed in the author's bibliography. Two of the 84 reproduced articles are by Wiener's colleague, I. B. Wexler, and the rest from the author's previous works, including 10 on technics of testing. This volume will be of service in many ways, not the least of which is to bring together the record of the monumental contribution of Wiener to the development of knowledge of the Rh system. Because of his important participation in all parts of this development, this book can serve as an up-to-date reference in this whole field. Yet the reader, by giving attention to the many bibliographic references listed with the articles, and by considering the sheer volume of space given to the Rh vs. CDE controversy, can know that others have labored in the same field and that there are differences of opinion on the subject. Though an impressively thick book, one cannot help wonder whether the photo-offset process should not have brought the price nearer the average pocketbook.— F. P. Thieme.

THE LEWIS BLOOD FACTORS IN AMERICAN NEGROES

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INTRODUCTION

The Lewis blood group system was discovered in 1946 by Mourant ('48), who found two antisera of identical specificity, agglutinating the red cells of 25% of bloods of a small series of English people. In a limited hereditary study, the agglutinin defined by these sera was shown to be genetically transmitted. The first of these antisera was obtained from a patient by the name of Lewis.

Andresen ('47) with a similar serum, studied a larger series of bloods of white adults and found that 21% possessed this agglutinin.

Soon after, Andresen ('48) discovered another serum which gave reactions which were almost completely antithetical to those of the earlier Lewis sera. The original serum was first called anti- L_1 , its corresponding agglutinin L_1 , and the new serum anti- L_2 and its corresponding agglutinin L_2 . Later, in order to avoid confusion with another human blood group system, Lutheran, the designations were modified, Le^a for L_1 and Le^b for L_2 (Andresen et al., '49).

Andresen found a much higher frequency of $Le(a+)$ bloods in infants, but found that the frequency of $Le(b+)$ bloods was essentially the same as in adults. This has not been confirmed. We have found that cord blood specimens are

¹ The authors wish to acknowledge the very helpful advice of Dr. P. Levine and Dr. A. E. Mourant.

essentially $\text{Le}(a - b -)$, and that the Lewis phenotype appears as an agglutinable characteristic of the red cells only after a few weeks of age (Rosenfield and Ohno, unpublished observations).

Another unusual feature of the Lewis system was that the two types of antisera were not completely antithetical since about 6% of group O bloods failed to react with either serum. Thus, three phenotypes were recognizable in adults: $\text{Le}(a + b -)$, $\text{Le}(a - b +)$, and $\text{Le}(a - b -)$. The particular anti- Le^b serum used by Andresen gave weaker reactions with A_1 bloods and more bloods of this subgroup failed to be clumped by either anti- Le^a or anti- Le^b sera. Brendemoen ('50) using an anti- Le^b serum, "Aagaard," in an investigation of the Lewis system reported that the agglutination by this antibody was probably independent of the A-B-O system. Hence, the weakness of reactions of A_1 bloods with the anti- Le^b serum of Andresen may be an expression of a peculiarity of certain anti- Le^b sera. Results with group B bloods were not reported by Andresen.

Andresen and Jordal ('49) described another antibody found in the serum of an $\text{Le}(a - b -)$ mother, which they called anti-X. This serum contained an anti- Le^a agglutinin and an incomplete antibody which agglutinated most other bloods when their cells were suspended in their own plasma or in albumin. In testing more than 300 blood samples, they found that all X-negative bloods were of phenotype $\text{Le}(a - b -)$ and that all bloods that were $\text{Le}(a - b -)$ were also X-negative. Andresen and Jordal suggested that X is an inherited factor and that an allele x also exists. Furthermore, they postulated that the "homozygote (xx) inhibits the development of phenotypes of the Lewis system." According to this theory the bloods of genotypes Le^aLe^a , Le^aLe^b , and Le^bLe^b would fail to be clumped by either anti- Le^a or anti- Le^b sera when their X type was xx .

Grubb ('48) found that all adults whose bloods were Le^a positive were non-secretors of A-B-O substances and that *almost all* persons who were Le^a negative were secretors of

A-B-O substances. This finding was corroborated by Race et al. ('49), and was further evidence that the Le^a factor behaved as a recessive character. Brendemoen ('49) and Grubb and Morgan ('49) demonstrated inhibiting Le^a substance in the salivas of most persons, being present generally to a greater extent in individuals whose red cells were Le^a positive. Similarly, it was found that most salivas showed inhibiting substance for anti- Le^b sera (Brendemoen, '50). Furthermore, Brendemoen ('49, '50) found inhibiting substance in sera for Le^a and Le^b antibodies dependent on the Lewis phenotype of the red cells; individuals whose phenotype was $Le(a-b-)$ did not contain either substance in their sera.

In the course of a recent study on the frequency of some of the more recently discovered agglutinogens in Negroes (Miller, Rosenfield and Vogel, '51), surprising results were obtained with the Lewis antisera. Schiff ('40) had found that the A-B-O non-secretor rate in Negroes was almost twice that for Caucasians. It was therefore anticipated that the incidence of $Le(a+b-)$ bloods for this racial group would be about twice that for Caucasians. Instead of the expected frequency of about 35-40%, the observed frequency for 200 bloods was found to be 23% as compared with 22.8% for 460 Caucasian bloods. However, bloods of phenotype $Le(a-b-)$ were more frequent (16%) in the Negro series as compared to the incidence of this type (5.7%) in Caucasians. While A-B-O secretor studies had not been performed in the earlier study it seemed possible that if most persons of phenotype $Le(a-b-)$ were non-secretors for A-B-O substances, then our data and that of Schiff would be in accord. This did not seem too likely since it was known that most Caucasian individuals of phenotype $Le(a-b-)$ were secretors of A-B-O substances.

The purpose of this study was (1) to continue the Negro series for their Lewis phenotypes in an attempt to discover the cause of the apparent discrepancy between our Le^a - Le^b frequencies and the results of Schiff for the secretor status

of A-B-O substances, and (2) to attempt to define further the relatively common phenotype $Le(a - b -)$ in this racial group, since it has been the 6% of bloods of this type that have been so troublesome to most investigators studying white populations.

MATERIALS

Two series of adult Negro subjects were selected as having particularly dark skins, since this is the only way available among American Negroes of assuring the highest possible percentage of African ancestry. In the first series of 111 subjects, blood and saliva specimens were studied. Venous blood specimens were obtained, the sera removed, frozen and stored. Three to 4 ml of saliva were procured from each subject and heated in a boiling water bath for at least 10 minutes; the coagula were thrown down by rapid centrifugation and supernatant fluids removed and stored in the frozen state. In the second series of 100 subjects, only blood specimens were obtained.

Prior to this study we had encountered 9 examples of anti- Le^a sera. All were obtained from individuals of Lewis phenotype $Le(a - b -)$. Where salivas were obtainable, it was uniformly found that these donors were secretors of A-B-O substances, but non-secretors of either Le^a or Le^b substance. All A-B-O groups and subgroups were encountered among the donors of these sera.

All of these 9 sera reacted specifically with the phenotype $Le(a + b -)$ at 37°C . If these sera were used undiluted at lower temperature, however, weak agglutination of red cells of Lewis phenotype $Le(a - b +)$ was observed if the A-B-O group of the test cells was O or A_2 . There was no agglutination at lower temperatures of bloods of phenotype $Le(a - b -)$, or of phenotype $Le(a - b +)$ if the latter were of group A_1 , B, or $A_1 B$. One of our anti- Le^a sera gave additional Le^b reactions of almost equal strength at room temperature. We believe this serum corresponds to the anti-X of Andresen and Jordal ('49). Simmons and Jakobowicz ('51) have interpreted

a similar serum as polyvalent: anti-Le^a plus anti-Le^b. Because absorption of our serum with Le(a — b +) red cells removed the anti-Le^b activity without affecting the anti-Le^a activity whereas absorption with Le(a + b —) red cells removed all antibody activity, it is more reasonable to assume that the anti-X of Andresen and Jordal ('49) is a cross-reacting Lewis antibody (anti-Le^x?) and that the majority of anti-Le^a sera contain a quantity of cross-reacting antibody in addition to specific anti-Le^a. We have since encountered one serum of this description that could be absorbed with either Le(a — b +) red cells or with Le(a + b —) red cells, leaving specific anti-Le^a or specific anti-Le^b; from the loss of potency from either absorption, however, it appeared that the bulk of the antibody was cross-reacting. Absorbed Lewis antisera are highly unstable and lose most or all of their antibody activity within a few days even though stored at —20°C.

We have had the opportunity to work with 10 examples of anti-Le^b sera. These have been derived from persons of group A₁, B, or A₁B. They demonstrated variable differences in their reactions dependent on the blood groups. In 9 of the 10 examples a secondary agglutinin could be demonstrated in undiluted serum. The reactions due to this secondary agglutinin could be eliminated by the addition of Sharp and Dohme A and B substances (which contains O substance) or could be absorbed along with the group agglutinins with washed red cells of the appropriate blood group and Lewis phenotype [viz., Le(a + b —)]. The addition of human A-B-O secretor saliva neutralized this agglutinin, but neutralized the Le^b antibody as well. The reactions of the secondary antibody were dependent on the blood groups, bloods of groups O and A₂ giving the strongest reactions. From these observations it is thought that the antibody accompanying anti-Le^b is probably anti-O². It is of interest to note that Brendemoen ('50) described the serum "Mathisen" which

²Morgan and Watkins ('48) designate that variety of anti-O inhibited by group specific soluble substances as anti-H.

may be a similar combination of anti-Le^b and anti-O agglutinins.

Producers of anti-Le^b always were of Lewis phenotype Le(a — b —). Where saliva specimens were obtained, they were found to be derived from non-secretors of A-B-O substances and Le^b substances. Their salivas either* did not contain any demonstrable Le^a substance or very minute amounts.

All of our anti-Le^a and anti-Le^b sera, when fresh and prior to inactivation, had the property of causing hemolysis. At 37°C., especially when trypsin-treated erythrocytes were tested, the Lewis antisera exhibited hemolytic activity in addition to agglutination. With aging of the sera or following their inactivation, only agglutination was observed. After loss of complement, trypsin treatment enhanced the agglutination with Le^a and Le^b antibodies.

Lewis sera used in this study. Two principal anti-Le^a sera were used. (1) Serum "Par," obtained from a donor of group A₁, Le(a — b —), secretor of A and O substances and non-secretor of either Le^a or Le^b substances; (2) serum "Ban," derived from a donor of group A₁B, Le(a — b —), secretor of A, B, and O substances³ and non-secretor of Le^a and Le^b substances. "Ban" is the most potent example of anti-Le^a we have encountered.

Two anti-Le^b sera were used. (3) Serum "Hir," from a donor of group A₁, non-secretor of A, O, or Le^b substances, and a very weak secretor of Le^a substance. The reactions of this serum with Le(a — b +) bloods were only slightly dependent on their A-B-O groups, for while some bloods of groups A₁ and B gave slightly weaker reactions than those of groups O and A₂, the number of bloods of the former groups failing to react with anti-Le^a and "Hir" were about the same as in the latter groups. When this serum was used in tests performed at lower temperatures (15–17°C.) an additional antibody was apparent. Bloods of type Le(a +

* Although the donor was group AB, the saliva specifically inhibited the anti-O agglutinin in eel serum and in several human sera.

b—) gave positive reactions dependent on the A-B-O groups. Blood containing the A_1 or B factor either failed to react or gave distinctly weaker reactions than those of groups O and A_2 . The secondary agglutinin was neutralized by the addition of Sharp and Dohme B substance or absorbed along with the group agglutinin by the use of packed red cells of group B, Le(a + b—). (4) the second anti-Le^b serum, "Fal," was from a donor of group A_1B , Le(a — b —). The secretor character for A-B-O, Le^a and Le^b substances was not determined. While fresh, at 37°C., this serum specifically agglutinated group O and A_2 bloods of phenotype Le(a — b +), whereas at 20°C., this serum agglutinated most bloods. When saliva inhibition tests were performed with this serum against group O, Le(a + b—) red cells at 20°C., the reactions were completely parallel to those obtained with eel serum (anti-O). Later, after storage, this serum gave specific Le^b reactions only against trypsin treated red cells of groups O and A_2 . For these two blood groups, serum "Fal" gave identical results with serum "Hir."

METHODS

Grouping and Lewis typing. From the blood clots 2% saline suspensions of red cells (washed once) were prepared and tested with Anti-A, anti- A_1 (absorbed B), anti-B, anti-Le^a and anti-Le^b sera. One drop (0.05 ml) of red cell suspension was mixed with two drops (0.1 ml) of serum. The first series of bloods were tested with serum "Par" (anti-Le^a) and serum "Hir" (anti-Le^b) whose group agglutinins were neutralized by the addition of B substance (Sharp and Dohme). The tests were performed at room temperature. After one hour the tubes were centrifuged and the resuspended sediments read grossly. The second series of bloods was tested with serum "Hir" as described, and with serum "Fal" (anti-Le^b) and with serum "Ban" (anti-Le^a) with red cells that had been trypsin treated (Rosenfield et al., '51). The tests with trypsin treated red cells were performed at 37°C. and the sediments read directly without centrifuging the tubes.

Inhibition tests. These were carried out for the first series only. The tests for the presence of A-B-O substances in salivas and Le^a and Le^b substances in sera and salivas were performed in two batches each on the specimens which had been frozen soon after they were obtained. The inhibition tests were all performed at room temperature using one drop of antiserum, one drop of either serum or saliva (undiluted or diluted), allowing the mixture to stand for 10 minutes or longer and then adding one drop of a 2% saline suspension of the appropriate red cells. After incubating for one hour the tubes were centrifuged and the resuspended sediments read with the unaided eye.

(a) Tests for secretion of A-B-O substances in salivas. The testing sera were anti-A, anti-B, and anti-O (eel) diluted with saline to a point where they gave 2+ reactions when one drop was added to one drop of saline and one drop of 2% red cell suspension of A₂, B, and O cells respectively. Undiluted saliva was used in determining secretor status; one drop of antiserum was mixed with one drop of saliva, allowed to stand for 10 minutes, following which one drop of appropriate 2% red cell suspension was added and the test centrifuged and read for agglutination.

(b) Tests for Lewis substances in sera. For the detection of Le^a substances in sera, one drop of anti-Le^a serum ("Par") was mixed with one drop of the subjects' undiluted sera, and after incubation, one drop of a 2% red cell suspension of group O, Le(a + b —) was added. Similarly, where sera was tested against Le^b antibody ("Hir"), group O, Le(a — b +) red cells were used.

(c) Tests for secretion of Lewis substances in salivas. In these inhibition experiments, undiluted saliva and saliva diluted 1:10 were tested routinely. In many cases, salivas diluted 1:5, 1:25, 1:100, and 1:1000 were also studied. In addition, many inhibition studies were made against trypsin treated red cells at 37°C., a technic which, we feel, yields the clearest results.

Tests for Lewis antibodies. The sera of all persons whose red cells were Le(a — b —) were tested with group O, Le(a + b —) and Le(a — b +) cells. Sera giving positive reactions were then tested against a larger panel of completely typed bloods to prove the identity of the irregular agglutinins. For the second series, the test cells were trypsin treated.

TABLE 1

Reactions of the bloods with the various Lewis antisera and their A-B-O groups

LEWIS PHENOTYPES	A-B-O GROUPS	ANTI-Le ^a		ANTI-Le ^b	
1st series		“Par”	“Ban”	“Hir”	
Le(a + b —)	All	++±		—	“Fal” ¹
Le(a — b +)	O and A ₂	±		++±	
	A ₁ and B	—		+± to ++±	
Le(a — b —)	All	—		—	
2nd series					
Le(a + b —)	All		++++	—	—
Le(a — b +)	O and A ₂		+	++±	+++
	A ₁ and B		— to tr.	+± to ++±	—
Le(a — b —)	All		—	—	—

¹ Tested against trypsin treated red cells.

RESULTS

The results of the testing of the bloods with the various antisera are shown in table 1. Weak Le^a reactions were obtained with bloods of group A₂ and O that were clearly positive with anti-Le^b sera. Such Le^a reactions were not obtained with bloods of group A₁, B or AB, indicating that these atypical reactions could not represent the heterozygous state of Le^a but must indicate the presence of a weak Le^b antibody in our anti-Le^a serum and that the activity of this Le^b antibody was subject to the phenomenon (“epistasy”) described by Andresen.

Lewis phenotypes. The phenotypes observed in the testing of 211 Negroes are presented in table 2, along with the frequencies observed in Caucasians in a previous study.

*Relation of Lewis phenotypes of A-B-O
secretor status*

1. All bloods of phenotype Le(a + b —) were obtained from individuals whose salivas were devoid of A-B-O substances.

TABLE 2

Lewis phenotypes in Negroes compared to their incidence in Caucasians

RACIAL GROUP	NO. TESTED	Le(a+b—)	Le(a—b+)	Le(a—b—)
		%	%	%
<i>Negroes</i>				
Present study				
1st series	111	22.4	56.8	20.8
2nd series	100	24.0	52.0	24.0
Combined series	211	23.2	54.5	22.3
Previous study	200	23.0	61.0	16.0
<i>Caucasians</i>				
Previous study	460	22.8	71.5	5.7

2. All bloods of phenotype Le(a — b +) were obtained from individuals whose salivas contained A-B-O substances.

3. Of the 23 bloods of phenotype Le(a — b —) 17 were obtained from A-B-O secretors, and 6 from A-B-O non-secretors. In 16 of these individuals, Lewis substances were detectable in their salivas to a sufficient extent to allow for interpretation of their Lewis status: 6 salivas that contained Le^a substance but little or no Le^b substance, failed to contain A-B-O substances; while 10 salivas that contained Le^b substance but little or no Le^a substance did contain A-B-O substances. Seven salivas gave negative reactions for both Lewis substances but did contain A-B-O substances.

Secretion of Le^a and Le^b substances in sera. The presence of inhibiting doses of Le^a or Le^b substances in sera was dependent on the Lewis phenotype of the individual involved as defined by their red cell agglutination reactions. Persons of phenotype Le(a + b —) regularly had inhibiting doses of Le^a substance in their sera and lacked Le^b substance in demonstrable quantity. The sera of persons whose phenotype was Le(a — b +) did not contain detectable amounts of Le^a substance but regularly contained inhibiting doses of Le^b substance. The sera from bloods of phenotype Le(a — b —) did not contain demonstrable amounts of either Lewis substance. Thus far, aside from the behavior of the Le(a — b —) cases the results are rather clear-cut and may be summarized as follows:

LEWIS PHENOTYPES		A-B-O SUBSTANCES IN SALIVA		LEWIS SUBSTANCES IN SERUM			
				Le ^a substance		Le ^b substance	
		+	—	+	—	+	—
Le(a + b —)	25	0	25	25	0	0	25
Le(a — b +)	63	63	0	0	63	63	0
Le(a — b —)	23	17	6	0	23	0	23

Lewis substances in salivas. The salivas from Le(a + b —) persons almost always had complete inhibition titers for Le^a substance in dilution of 1:100 and generally in dilution of 1:1000. All but 4 of the 25 had demonstrable Le^b substance in their salivas diluted 1:10. The salivas derived from persons whose phenotype was Le(a — b +) almost regularly contained Le^b substance in dilution of 1:1000. Their Le^a substance content was demonstrable in 1:10–1:100 range. In general our results are similar to those obtained by Brendemoen ('50). However, actual inhibition titers are not comparable because of the differences in saliva-antibody proportions used and the probable variations in the potency of the testing sera. It was in the saliva inhibition studies from Le(a — b —) donors that the most interesting results were obtained. Those that were non-secretors for A-B-O

substances behaved like $\text{Le}(a + b -)$ cases that were weak secretors for Lewis substances. Le^a substance was always present in 1:5 dilution and generally in 1:10. Inhibition of anti- Le^b was just detectable in undiluted saliva. Of the 17 instances of $\text{Le}(a - b -)$ that were secretors for A-B-O substances, 10 behaved as $\text{Le}(a - b +)$ in that while secretion of Lewis substances was variably diminished, proportionately there was greater inhibition of the anti- Le^b serum. In the remaining 7 cases, the salivas were almost completely without demonstrable Lewis substances, although very slight inhibition was occasionally evident for one or both Lewis antisera in undiluted saliva.

Lewis antibodies. Although all sera (first series) from $\text{Le}(a - b -)$ bloods were tested for Lewis antibodies, it was only among those 7 whose salivas contained A-B-O substances but lacked Le^a and Le^b substances that antibodies were found. Three definite examples and a probable 4th were observed. The strongest two were fair examples of anti- Le^a with weaker anti- Le^b activity. The third, a weak anti- Le^a , did not seem to react with $\text{Le}(a - b +)$ bloods. The 4th, probably a still weaker example of anti- Le^a , also lacked detectable anti- Le^b activity. In the second series the sera were tested against trypsin treated red cells of the various Lewis phenotypes. Four definite examples of anti- Le^a giving weaker reactions with $\text{Le}(a - b +)$ bloods were observed.

DISCUSSION

In the present study, 31 of 111 subjects, or 28%, were non-secretors of A-B-O substances. This does not compare too favorably with the frequency of 38.8% found by Schiff ('40) in 178 tested as the difference is nearly significant. ($\chi^2 = 3.54$ for 1 d.f.; $P = .07$). Since we performed this work, Barnicot and Lawler ('53) reported a study of 141 blood with 125 saliva specimens from West African Negroes. They found 37.6% to be non-secretors of A-B-O substances, agreeing very closely with Schiff's results. However, they encountered two $\text{Le}(a - b +)$ individuals who were non-secretors, and

they had 39% of the phenotype Le(a—b—) among 105 bloods of groups O, A, and A₂. They reported 38.4% of salivas to be devoid of any Le substance.

The present study differs in one significant aspect from the works of Schiff ('40) and of Barnicot and Lawler ('53), since we studied *undiluted* saliva as well as diluted. At no time have we encountered "non-specific" inhibition of anti-serum by undiluted saliva. But we have encountered a considerable number of individuals who are secretors of only small amounts of A-B-O substances in their saliva.

As previously mentioned, it has been the finding of Le(a—b—) bloods that has complicated the explanation of the Lewis system. Were these not present then the allelic genes *Le^a* and *Le^b* and their close linkage or their identity with *s* and *S* (Schiff's genes for non-secretion and secretion of A-B-O substances) would permit a simple representation of the system. Originally, Andresen ('48) postulated a third allele, *Le^c*. This would not seem to explain the facts, since if *Le^c* were linked with either *S* or *s* (but not both) then persons of Lewis phenotype Le(a—b—) would either be all non-secretors or all secretors for A-B-O substances; whereas actually either secretor status can exist with this phenotype.

Andresen and Henningsen ('51) later tried to explain the Lewis system in another way. They described a blood group property which they claimed was influencing the system's phenotypical expressions. While this seemed to explain the Lewis system, we cannot agree that the serum describing the "new" blood group property actually exists. From the description of the serum called anti-X by these workers, and our own experience with a similar serum, we believe anti-X really to be anti-*Le^a* cross-reacting with *Le^b*. Simmons and Jakobowicz ('51) have interpreted anti-X similarly, but implied that specific anti-*Le^b* was always present.

Grubb ('51) studied both the blood and saliva of 1,000 Scandinavians and concluded that the gene for *Le^b* was probably identical with the gene, *S*, for ABO secretion. Because of the fact that 90.2% of salivas contained *Le^a* substance,

he proposed that Le^a was not allelic to Le^b but was very possibly identical with the X factor of Andresen ('51). From the description of the two anti- Le^b sera employed in Grubb's study, it would appear that the antibody activity in both was predominantly anti-O rather than anti- Le^b . A similar serum is described in the present report (serum "Fal"). Obviously Le^a could not be allelic to O. And since the anti-X of Andresen ('51) appears to be cross-reactivity of anti- Le^a with Le^b , Grubb's conclusion that the secretion of Le^a factor was identical to X is in essential agreement with the present observations.

It is possible that there may be a genetically simple property defined as ability of red cells to react with either or both of the antibodies anti- Le^a and anti- Le^b . Only family studies will clarify this point.

The present study of the Lewis system in Negroes shows that the bloods and salivas of these donors fall into three classes: (1) those whose bloods are agglutinable by either of the Lewis antisera (where the Andresen phenomenon is not a factor) and whose salivas contain large amounts of Lewis substances, (2) those whose red cells are of Lewis phenotype $Le(a-b-)$ but whose phenotype can be determined as $Le(a+b-)$ or $Le(a-b+)$ on the basis of smaller amounts of Lewis substances in their salivas, and (3) those that cannot be typed either as $Le(a+b-)$ or $Le(a-b+)$ because of the inagglutinability of their red cells with Lewis typing sera and the inability to detect Lewis substances in their salivas. It is in this latter class that the Le^a and Le^b antibodies have been found. No exceptions were observed to the absolute linkage between the Lewis system and the A-B-O secretor system where a Lewis phenotype could be defined on the basis of red cell type or the presence of Lewis substances in saliva. This suggests that the cases of type $Le(a-b-)$ which can be typed on the basis of Lewis substances in the saliva represent deficiencies in Lewis antigens and may be designated as subtypes: Le^a1 , Le^a2 . . . and Le^b1 , Le^b2 .

. . . To fit the facts, however, one other postulate must be added: Le^a and Le^b substances must partly cross-react, since the natural antibodies are never observed except where the individual is deficient in both factors. This could also explain the presence of Le^b inhibiting substance in the salivas of $\text{Le}(a + b -)$ individuals and the presence of Le^a substance in the salivas of all $\text{Le}(a - b +)$ persons.

The weakness or absence of reaction of bloods with certain anti- Le^b sera dependent on their A-B-O blood groups is of great interest but not understood. In our own experience, anti- Le^b antibodies have almost always occurred in combination with inhibitable anti-O antibodies, and both antibodies have shown some weakness or absence of reaction with red cells of groups A_1 , B, and AB. Rather than explaining the weakness of Le^b reactions with bloods of groups A_1 , B, and A_1B by "epistasy," it is very possible that these poor reactions are dependent upon the weakness or absence of O (or H) factor in such bloods. This implies that the strength of Le^b reactions is frequently dependent upon the presence of O in the test blood to potentiate the reaction by cross-reactivity.

SUMMARY

1. In a study of the bloods of 211 Negro subjects, the frequencies of the Lewis phenotypes were found to be as follows:

$\text{Le}(a + b -)$	23.2%
$\text{Le}(a - b +)$	54.5%
$\text{Le}(a - b -)$	22.3%

2. The frequency of the A-B-O secretor status of 111 Negro subjects was found to be 72%. This differs from the result of Schiff ('50), who found 61% ($\chi^2 = 3.54$ for 1 d.f.; $P = .07$).

3. In the 111 Negro subjects where saliva specimens were available for study, the salivas and sera were examined for the presence of both A-B-O and Lewis substances with the following results:

a. In individuals of Lewis phenotype $\text{Le}(a + b -)$, Le^a substance could always be demonstrated in both serum and

saliva, and these individuals were always non-secretors of A-B-O substances. Le^b substance was also present in the saliva of these individuals, but not in their serum. The amount of Le^b neutralizing activity never equalled the amount of Le^a activity in these salivas.

b. In individuals of Lewis phenotype $Le(a - b +)$, Le^b substance could always be demonstrated in both serum and saliva, and these individuals were always secretors of A-B-O substances. Le^a substance was also present in the saliva of these individuals, but not in their serum. The amount of Le^a neutralizing activity never equalled the amount of Le^b activity in these salivas.

c. Some individuals of Lewis phenotype $Le(a - b -)$ secrete Lewis substance in their saliva. When the substance is Le^a , or predominantly Le^a , the individual is a non-secretor of A-B-O substances. When the saliva contains only Le^b substance, or more Le^b than Le^a substance, it also contains A-B-O substances.

d. A small number of individuals of Lewis phenotype $Le(a - b -)$ are devoid of Lewis substance in their saliva. In the sera of 4 out of 7 such individuals, anti- Le^a antibodies could be identified. These individuals were secretors of A-B-O substances.

4. Most anti- Le^a sera weakly agglutinate group O and A_2 bloods of phenotype $Le(a - b +)$. This appears to be anti- Le^b activity.

5. Most anti- Le^b sera contain a weak anti-O agglutinin, but do not contain anti- Le^a .

6. To explain the Lewis phenotype, $Le(a - b -)$, a series of antigen deficient alleles is postulated.

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SICKLE-CELL TRAIT CARRIED BY VEDDIANS.—The finding at high frequency of the sickle-cell trait in the Veddians of South India has altered our view that the gene is essentially African. . . . The sickle-cell trait is only patchily distributed in Africa. The highest incidences have been reported from East Africa where they varied from 30 to 45% in some Bantu tribes. Other Bantu tribes in East Africa have lower incidences of the trait and in Uganda this seems to go parallel with the degree of dilution by recent Hamitic-speaking invaders. If one considers the highest incidences only, one finds that they fall towards the west; at the coast they are 20–25%. They also decline the further one goes south and are about 10% in Northern Rhodesia, to become practically nil in South Africa. The Bushmen have no sickle cells at all. . . . Similarly, the “yellow” pygmies of Central Africa are virtually free of sickle cells. Thus the trait is not a universal African feature and one may suggest that it entered the continent with Veddian blood well after the African races had established themselves. Most Veddians are found today in South India, but pockets have been described in Persia and in the Hadhramaut which brings them to the former land bridge between Asia and Africa in the region of Aden. The trait seems to have entered Africa from the north-east, has been spreading southwards and westwards, and seems still to be in the process of establishing itself.—H. LEHMANN. The Sickle-cell trait: Not an essentially Negroid feature. *Man*, vol. 53, no. 5, January, 1953, pp. 9–10.

MEMORIUM



EARNEST ALBERT HOOTON

Doctor Hooton died unexpectedly on May 3, 1954, and anthropology lost one of its great figures. He was imaginative, stimulating, persevering, brilliant, and above all helpful, and it is hard to imagine what physical anthropology in this country would be today without him.

He was born in Clemansville, Wisconsin, on November 20, 1887. He went to high school at Manitowoc, and graduated from Lawrence

College in 1907. As a senior, he took the examinations for a Rhodes Scholarship and was qualified. Instead of going at once to Oxford, however, he went to the University of Wisconsin to do graduate work in the classics, being awarded the M.A. in 1908 and the Ph.D. in 1911. While still there, his interest was drawn by a book he found in the library, apparently on the tribes described by classical writers, and he decided, he has said, to take a flier in anthropology when he got to Oxford.

He went there in 1910, and entered University College. The master made him at home by saying they had had one American before, and had not liked him. Hooton next attended his first seminar on Sophocles and found it not to his taste. His flier in anthropology became a flight, though he carried his classical training in writing along with him: he turned to R. R. Marett and took the diploma in anthropology in 1912. In 1913 he was appointed instructor at Harvard, where he remained the rest of his life.

He made himself nationally known by his familiar books on man's evolution and nature. He created wide interest in the subject, writing with wit, simplicity and a good-humored attention to the deficiencies of man, but always with the desire to convey information of a scholarly but comprehensible kind to the reading public.

His originality of mind, his tenacity of purpose and his freedom of approach are shown in his professional work. Where anthropologists of the generation just before his described a racial type or observed the variations of the humeral shaft, Hooton's interest, somewhat like that of Boas, lay in trying to see the variations within a physical population: the way in which it might reflect its racial origin, or respond to its environment, and what lay back of the assortment of forms and variations which any population appeared to produce. Such an interest appeared in different manifestations in his main investigations: analysis of the crania of the Canary Islands, or the Pecos Pueblo; the work on criminals; the Irish Survey; the Grant Study — or the investigations to which he set his students: the Riffians, the races of Europe, the changing physique of college students, the hybrid descendants of the Bounty mutineers, the origin of the native Australians. It was surely what caused him to champion constitutional typology, and it is strongly reflected in his own interpretations of the nature of races and racial history. But it was hardly a limiting influence, and the above list of projects shows the fertility and breadth of his ideas, in the areas of work he chose, or suggested to his students.

He had, therefore, much to offer his graduates, and he sent them out with broad views of their own, evident in their subsequent diverse

professional development. However, it was not simply his intellectual force, and the attractiveness of his teaching, which gave his students so much. He was, of course, a fascinating lecturer. He was, as the world knows, a supremely gifted writer, with an exemplary style below all the surface humor and vivid expression. (Those who are inclined to think first of his newspaper pronouncements and his collected Harvard Club addresses should turn sometime to such a work as "Crime and the Man" for a lesson in expository English.) His grace as a speaker was unexcelled, and he was the delight of an Association dinner when he could be prevailed on to talk.

But his own nature was undoubtedly the key to his effect on his world and his students. He sounded brilliant, and he was: no talk with him failed to be a mild excitement, recognized mainly by the feeling that one's ownself had suddenly become a fund of ideas (which was not the case at all). He was made to sound caustic, in the image the reporters were apt to give him, but he was not: when he spoke adversely it was always against the Pharisees, against a group idea, and never against an individual colleague. He did not indulge in small-print controversy in the rear pages of journals; when he named a name in meeting or in print, it was to praise it. He was actually enormously good-humored and totally lacking in pettiness; he never took umbrage, and accepted direct attacks, printed or spoken, with unruffled magnanimity; this was simply not the kind of thing that could annoy him.

He was generous in every way: his generosity of ideas to his students was accompanied by a generosity of time and sympathy, and his genuineness in all of this was why he attracted and held students. He was fair-minded in the greatest degree, and strong in the prosecution of his projects, and he set a good example to his followers in these things. He was a leader, but through warmth of character and through intellectual companionship, not through any academic authority. These qualities are the source of his legacy to anthropology, since a large proportion of the country's physical anthropologists are either the men he trained, or trained by the men he trained.

His recognitions and honors were plentiful. He was a founder of the Association, and served as President from 1936 to 1938. He was Associate Editor of the *Journal* from 1928 to 1942, a span of 29 volumes. He was named for the Viking Fund Medal and Award in 1948, being its second recipient. He was a member of the National Academy of Sciences and had been Vice President of Section H of the American Association for the Advancement of Science. He was given the D.Sc. in 1933 by Lawrence College, and just before he died he was notified that he was to receive the Litt.D. from the University of Wisconsin; the award was made after his death.

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BEGINNING OF PHOTOGRAMMETRY.—Collectors of photographs, illustrative of the races of man, have experienced the greatest difficulty in questions of comparison of measurement of individuals by some common standard. Latterly a plan, simple and answering the purpose, has been put in practice by myself. . . .

A stout frame of wood, 7 feet by three, is neatly ruled along its inner side into divisions of two inches; small nails are driven into these ruled lines, and fine silk thread is strained over them, dividing the included surface by longitudinal and latitudinal lines into squares of two inches every way. Against this screen the figure is placed, the heel fairly on a line with one of the strings; the iron prop to support the object is pressed firmly in its place at some distance from the background; for, by this means better defined outlines are secured than if the man stood directly against a solid screen on which lines might have been scored. By means of such photographs the anatomical structure of a good academy figure or model of 6 feet can be compared with a Malay of 4 feet 8 in height; and the study of all those peculiarities of contour, which are so distinctly observable in each group, are greatly helped by this system of perpendicular lines, and they serve as good guides to their definition, which no verbal description can convey, and but few artists could delineate. . . .—J. H. LAMPREY. On a method of measuring the human form, for the use of students in ethnology. *J. Ethnol. Soc. London*, n.s. vol. 1, 1868-69, pp. 84-85.

REVIEWS

RACES MÉLANODERMES ET LEUCODERMES, PIGMENTATION ET FONCTIONNEMENT CORTICO-SURRÉNALIEN.
By Jean Leschi. Masson et Cie, Paris. 1952. 109 pp. 910 Francs.

During the past 10 years much light has been shed on the physiology of the adrenal cortex. We now have a considerable body of data on its role in the regulation of water and electrolyte balance, in carbohydrate metabolism, and on tissue reactions to damaging agents. Much less is known about the relationship between adrenal function and pigmentation of the skin. Doctor Leschi's monograph attempts to relate adrenal function to the production of racial skin pigmentation. It is the opinion of the reviewer that her data are interesting, but that they do not establish such a relationship.

Her thesis in brief is that the Negro has a relative hypoadrenocortical function which renders him more pigmented than the White. She supports this contention with data showing that the Negro has lower adrenal weights and volumes, lower mean values for serum sodium and chloride, as well as serum potassium and copper levels higher than the corresponding values for Whites. In addition to differences in "racial" chemical morphology, she describes functional endocrine differences between the Negroes and Whites whom she studied: ingestion of potassium was followed by hyperkalemia more marked in the Negroes than in the Whites, and the administration of DOCA prevented this more effectively in the Negroes. These considerations led the author to conclude that the Negro is hypoadrenal and that "le rôle des surrénales dans la mélanogénèse chez l'homme a été précisé."

Unfortunately, several difficulties impair the validity of this conclusion. First, the groups studied probably do not constitute valid samples of the two races, the data concerning adrenal weights and volumes were taken from older American studies, and there are no serum electrolyte values to accompany these data, whilst there are no weight or volume data on the African and European groups whose electrolytes she studies. Yet the data are combined and presented as correlated measures of adrenal function in the two races. Second, the reported weights and volumes of Negro male adrenals are greater than those for White females, and the gland weights of Negroes of "asthenic" and "intermediate" body types were greater than those

of "pyknic" and "dysplastic" Whites; these findings are hard to reconcile with the concept that all Negroes are darker than all Whites because of hypoadrenocorticism. Third, the reported "racial" differences between serum sodium and chloride levels are probably neither clinically nor statistically significant. Fourth, the elevations of serum potassium and copper in the Negro can hardly be considered in themselves measures of adrenal cortical function, and the author's speculations and interpretations regarding these two elements are difficult to justify. For example, on the basis of a reported relationship between serum copper and thyroid function, she takes elevated copper as indicative of hypothyroidism without performing basal metabolic rates, protein bound iodine levels or glandular uptake of I^{131} . Then, finding that Negroes have higher serum copper than Whites, she postulates that the thyroid must be concerned with melanogenesis. A racial difference of 40 γ in mean serum copper, measured in Paris, was greater than the difference between the levels between Negro serum coppers as measured in Paris and Dakar (18 γ), yet the data are interpreted as consistent with hypothyroidism in warm climates and not as indicating hypothyroidism in the Whites. The author tends to assume that the levels found in the White subjects are "normal," and treats Negro levels, when different, as "abnormal." A 5th defect in her argument lies in her failure to realize that pigmentation in clinical hypoadrenocorticism is only one of a complex of features, most of which are very much in evidence by the time pigmentation approaches a Negroid character. Hypotension and small heart size are universal findings in Addison's disease, yet Negroes probably have more and severer hypertension than Whites. Also present in Addison's but absent from Negroes as a group are sterility, hypoglycemic crises, calcification of the cartilages of the ear, eosinophilia and lymphocytosis. Finally, the role of the pituitary is not adequately treated: Doctor Leschi is not impressed by the fact that hypoadrenocorticism secondary to hypopituitarism is never accompanied by pigmentation. This observation has long been taken to suggest a pituitary source for human pigmentation similar to that present in much of the animal kingdom. Recent studies by a number of authors have shown that ACTH contains a considerable amount of a substance, presumably intermedin, which causes melanophore expansion. This is in keeping with the clinical observation that ACTH treatment may cause melanosis.

This monograph presents a large quantity of interesting data on biochemical differences between some samples of Negroes and Whites. Some are original, some are not; some are significant, some are not, but they probably do not delineate racial differences in adrenocortical function. The groups studied do not represent "races," and the

differences are not characteristic of the groups. Also, the parameters measured are often not related to the adrenal cortex, and functional states are not revealed by the type of measurement recorded.

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LES RACES DE L'EUROPE. By Marc-R. Sauter. 341 pp. Payot, Paris. 1952.

This, the latest of the three books entitled *The Races of Europe* is also the shortest, being only 341 pages long (Ripley, 1899; 624 pages, not counting the 160 pages supplement; Coon, 1939; 739 pages). Furthermore, Sauter's book is the easiest reading of the three and, of course, more up-to-date than its forerunners. For these reasons it would make an excellent textbook, if only the average American student could read a foreign language.

The *Introduction* begins with a discussion of the concepts and definitions of race, language, and nation (pp. 9-17) and a short review of the languages spoken by European peoples (18-34). Then follows a chapter on racial traits and anthropological techniques, devoting 14 pages to anthropometry, 2 pages to physiology (primarily growth), 5 pages to serology (ABO, MN, and Rh) and 1 page to pathology.

The *First Part* (58-134) discusses, in three chapters, the archaeological and historical background of the European population: "From the primitive hominidae to homo sapiens"; "From the first farmers to the Pax Romana"; "From the invasions of the barbaric tribes to the Displaced Persons." Sauter has been so cautious that in the discussion of Piltdown Man hardly any changes will become necessary in a new edition. He has been prudent enough to insert a couple of question marks even in the illustration.

The *Second Part* (135-320) deals with the present: Sauter begins by discussing different systems of classification. He presents first, on charts and in the text, the classifications of the races of the world of Deniker, Eickstedt, Montandon and Montagu. Then he reviews the classifications of European races of Ripley, Coon, Eickstedt, Guenther and Czekanowski, dealing in detail with Coon (approximately 6 pages plus a map and a chart) and Eickstedt (map and chart) and finally also mentioning, but hardly more than mentioning Biasutti. In addition, the systems of Deniker, Montandon, and Montagu are listed in an accompanying chart. Classifications by others

like Hooton, Kraitschek, Nordenstreng, Weinert, Saller, Bunak, Birket-Smith, Lundman, are not presented at all; the author, quite consciously (and rightly) does not attempt to give an exhaustive survey of previous classifications. In this part genetics does not play a role.

Next Sauter examines the European distribution of pigmentation, stature, and skull index, and, in 8 pages, of blood groups (ABO; Rh).

Chapters 8 and 12 (pp. 179-320) make use of the knowledge conveyed in the earlier chapters for a description of the peoples of Europe (including the Near East and North Africa). In these chapters, which fill approximately half of the book, a balance between the older, anthropometric approach and the genetic approach (restricted, however, to blood groups) has been achieved. An admirable amount of important data, diligently collected and ably presented, has been compiled in these pages and will save many a reader a lot of time which he otherwise might have to spend on hunting for such information.

Depending on the reader's place in anthropology he will call Sauter either a man capable of presenting a synthesis of different trends in our field or a conservative who is not willing to give up the obsolete. A considerable part of his book (as may be inferred from the above) is devoted to the "classical methods of anthropometry" (171) and to the description of what he himself calls "des caractères phénotypiques superficiels, nuancés; et, de surcroît, plus ou moins soumis aux influences du milieu physique et social" (171). Sauter is by no means prepared to abandon these methods. He believes in the existence and reality of the races described by the older school (321 f.) and perhaps even in the three main races of Europe (16). Although he concedes a special position to the Basques whom he calls "hyper-European" and "more than white" (256, 269) he seems to hesitate to accept them as a race (254). He admits that blood groups should be taken into account for the classification of races but stresses the "fragility" of the "more pleasant than solid" picture drawn by geneticists who may "hope to arrive at valid results" [for the racial history of Europe] only if they utilize the older anthropological methods as well (178). He himself tries to combine the anthropometric with the genetic approach (e.g. 219).

Boyd's *Genetics and the Races of Man* came too late to be used by Sauter (54, n.); so did Kherumian's *Génétique et anthropologie des groupes sanguines* (178, n.). Part of the material of these books, however, was known to Sauter and has been made use of in his work.

The index is unusually short and omits not only all names of authors but also all references to prehistory and archaeology. The bibliography (324-330) is restricted to the most recent literature (p. 7); it proves

how widely read the author is but frequently leaves the reader out in the cold: many works to which the text refers only by author's name are not listed in the bibliography, and even publications which Sauter recommends especially to the attention of his readers, like J. Millot (53, 54, 56), are missing. On the other hand, some books which are named in the bibliography appear also in the text with full title.

There are other inconsistencies and flaws. The number of losses which the Polish Jews suffered during World War II is given twice (132 and 314) while those of the German and Baltic Jews do not figure at all in the compilation of losses in the Jewish population. It is less important, perhaps, but, I assume, it will be rather amusing to the readers of this journal to note that Sauter regularly quotes Frl. Schwidetzky as Mlle. Schwidetzky (202, 204, 208), but calls J. Lawrence Angel just as persistently — *Miss* Angel (106, 107, 223). (Perhaps I should add for Professor Sauter's information that the French equivalent of Lawrence is Laurent, not Laurence.)

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THE AFRICAN MIND IN HEALTH AND DISEASE. A STUDY IN ETHNOPSYCHIATRY. By J. C. Carothers. (World Health Organisation Monograph Series No. 17.) 177 pp. World Health Organisation, Geneva. 1953. \$2.00.

"Africans" as defined by the author are primarily members of the "Negro" (West African), Bantu, and Nilote groups. As particularly relevant elements of African environment which affect mental health he discusses: the very high infestation rates of malaria, trypanosomiasis, bilharziasis, hookworm, dysentery, ascariasis, taeniasis, pneumonia and tuberculosis; the chronic state of malnutrition in most Africans (giving particular attention to children's kwashiorkor); and the cultural environment. In contrast he quotes with approval statements concerning possible racial differences in mental make up, but he rejects this element later in favor of environmental explanations. He surveys the ((inconclusive) work on Negro brain anatomy, histology, and electrophysiology.

In speaking of the general character of African mentality, while skeptical as to the value of intelligence tests, he accepts the reality of certain stereotypes concerning the "childlike" traits in the African Negro, himself emphasizing the following three. (1) inability to see events as elements in a total situation, (2) tendency to follow routine

procedures, (3) lack of interest unless stimulated by direct emotional or personal appeal. Doctor Carothers interprets these traits as culturally conditioned, singling out childhood experiences (weaning, etc.). He thus follows the fashion introduced into anthropology by M. Mead and A. Kardiner. Anthropologists have recently become a little weary of this method which though occasionally providing brilliant insights is not easily controlled because of its extreme subjectiveness, and often does not square with the facts (see Kluckhohn's chapter on "Culture and Behavior" in *Handbook of Social Psychology*, ed. Gardner Lindner, Cambridge, 1954). In the opinion of the author African psychology and psychopathology can, on the other hand, just as well be causally related to chronic infection and malnutrition. He never makes a final choice on this issue.

After carefully weighing all the available data the author comes to the conclusion that the incidence of mental disease among African Negroes is only one-fourth of that encountered today in England and the U.S.A. (It is known that the North American Negro shows a considerably higher incidence than the North American White). The forms of mental disease among Africans are, according to the author, the same as in the West. Schizophrenia is prevalent, manic states are rare, depressive states and suicide extremely rare. Later when it becomes obvious from the author's clinical descriptions that African schizophrenia is not like Western schizophrenia, African manic states not like Western manic states, and that there remains a high percentage of unclassified cases, one wonders how meaningful the use of Western categories is in African psychiatry. No explanation is given by Carothers of the amazing incidence and character of mental disease in Africa which has also been suggested by earlier observers.

If we examine Doctor Carothers' discussion of causes in the light of European experience, we find that rural Europe emerged about 400 years ago from a mental-cultural state in many ways comparable to the African, and about 100 years ago from a similar state of chronic malnutrition and infestation. Yet it is highly doubtful whether mental disease has subsequently increased. It is certain that it has not decreased. In light of this, none of the author's explanations of the rates or nature of African mental disease seem very definitive; and for that matter, none of the explanations offered for other places and by other authors are completely satisfactory. This does not mean that we should not fight malnutrition, infestation, and cultural mal-organisation; it simply means that we know still very little about basic causes of mental disease in Africa, or elsewhere.

I would be distressed if these melancholic comments were to be interpreted as a lack of respect or sympathy for Doctor Carothers' book. The author has done an excellent job in surveying the available

sources, which included his own rich experiences of 21 years of practical psychiatry in Africa, and in judiciously analyzing this fascinating material. The book is very readable (a feature having unfortunately become so rare that it has to be emphasized). It will be a valuable source of information and stimulation for further thought and work in a field the very incompleteness of which should challenge the pioneers of our time.

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NOYES' ORAL HISTOLOGY AND EMBRYOLOGY. By Isaac Schour. Lea and Febiger, Philadelphia, Pa. 1953. 7th ed., 448 pp., 290 figs., 18 plates.

In recent years the teeth have become increasingly important to the physical anthropologist. Weidenreich and Zuckerman have stressed the value of dental morphology in human paleontology; Schultz has analyzed eruption sequence in Primates, including Man. Dahlberg, Kraus and Lasker are suggesting the discreteness of dental morphology as possible genetic traits; Stockard and his associates have conducted a comparative endocrinological and hybridization study of dento-facial traits in dogs; Broadbent, Brodie, and many others, have alerted us to the role of the dentition in cephalo-facial growth and development. It behooves students and teachers of physical anthropology to learn all they can about the human dentition. The teeth figure largely in evolution, race, genetics, growth—all subdivisions or aspects of our science.

Noyes' book has long been a classic in the dental field, especially with reference to developmental and microscopic morphology. In this, the 7th and revised edition, Schour has retained the traditional framework of the book, while stressing the dynamic interrelationships of tooth and bone in pre- and postnatal growth. I advise students in physical anthropology to read and master Chapters XIV on "Bone," XVIII on "Postnatal Development of the Face and Oral Cavity" (especially the summarizing table on pp. 302-303), XIX on "The Eruption of the Teeth," XX on "The Deciduous Dentition," and XXIII on "Comparative Dental Histology." Cranial and dental morphology have long played a prominent role in our science; they will continue to do so.

I recommend this book unreservedly to my colleagues in physical anthropology.

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VARIETIES OF RACIAL TEMPERAMENT.—Mr. Alfred R. Wallace said that, as a small contribution to the subject, he would venture to point out that there were certain mental characteristics which in two at least of the primary [racial] groups were as well marked and as constant as the physical characters by which Professor Huxley had defined them. The great Mongoloid group, for instance, was distinguished by a general gravity of demeanor and concealment of the emotions, by deliberation of speech, and the absence of violent gesticulation, by the rarity of laughter, and by plaintive and melancholy songs. The tribes composing it were preeminently apathetic and reserved; and this character was exhibited to a high degree in the North-American Indian, and in all the Malay races, and to a somewhat less extent over the whole of the enormous area occupied by the Mongoloid type. Strongly contrasted with these were the Negroid group, whose characteristics were vivacity and excitability, strong exhibitions of feeling, loud and rapid speech, boisterous laughter, violent gesticulations, and rude, noisy music. They were preeminently impetuous and demonstrative; and this feature was seen fully developed both in the African Negro and in the widely removed Papuan of New Guinea. This striking correspondence of mental with physical characters strongly supported the view that these two at least were among the best-marked primary divisions of our race.—Discussion following paper by T. H. Huxley. On the geographical distribution of the chief modifications of mankind. *J. Ethnol. Soc. London*, n.s. vol. 2, 1869–70, pp. 404–411.

HYAENAS VERSUS AUSTRALOPITHECINES AS AGENTS OF BONE ACCUMULATION

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SEVEN FIGURES

Since the Revrend William Buckland wrote his *Reliquiae Diluvianae* (1823), anthropologists and paleontologists have accepted unquestioningly his theory that the agent chiefly responsible for large accumulations of animal bones in caves and rock fissures is the hyaena.

Despite the concomitant evidence of human occupation (vide also Abel, '35, p. 322), Pleistocene collections of bones found in caverns are presumed to be, in the main, the work of hyaenas, which are even regarded as inhabiting the caves and fissures intermittently between periods of human occupation. The probability of all these collections of bones having resulted from the handiwork of early man or proto-human creatures is overlooked because some of the bones bear marks that have been made by rodents or have been interpreted as due to the teeth of carnivores.

Breuil ('39) clearly revealed, by his study of the bones and teeth found at Choukoutien in China, that *Sinanthropus* employed bones as weapons and tools. There is a very striking similarity between the objects of long-bone, horn-core and jaw-bone used as implements by *Sinanthropus* at Choukoutien and those found in the *Australopithecus* deposits at the Makapansgat Limeworks, Potgietersrust. These similarities indicate that man had begun his tool-employing, if not his tool-making activities at the *Australopithecus* phase of his existence.

Dart, in 1926 and later ('49) in more detail, showed that the broken bones and fractured skulls associated with the proto-hominid *Australopithecus* proved that these creatures possessed "manual dexterity and implemental intelligence." I have been intimately associated with the work of sorting the Makapansgat Limeworks dump for the last 6 years, having initiated it in 1948 and having been in charge of it annually since that time. The steadily accumulating knowledge of the human features of the Australopithecinae and of their carnivorous diet illustrated by the associated fauna prompted this direct enquiry into the hyaena theory. Its outcome denies the hyaena theory as an explanation of Pleistocene or Pliocene bone accumulations found in South Africa or elsewhere throughout the world.

The scientific study of the behavior and habits of hyaenas, though still in its infancy, can hardly be said to have advanced greatly since Buckland wrote in 1823. The hyaena of literature seems to be regarded firstly as a creature cracking or crushing every bone it happens to see and secondly, as one having a propensity for collecting masses of bones in caves and rock fissures. No evidence to my knowledge has ever been collected to support either of these two basic postulates. The notions current in Europe and America on these matters are necessarily based on the assertions of early travellers in Africa whose dramatic claims do not tally with observed facts.

In Africa, fortunately, hyaenas have been under considerable supervision for the past century and are still living in the wild state. The object of the investigation, summarized in this paper, was to discover whether hyaenas ordinarily crush bones with their teeth and where they customarily did it. Did they in fact have a bone-accumulating habit? In addition to excavating a hyaena "lair," I ventilated the matter widely in the press and addressed letters to various individuals who might, from their vast experience with wild game, be able to give an authoritative opinion on this matter, some of whom were kind enough to answer in detail by letters that

have been filed in the anthropological correspondence catalogue of this department.

STATEMENTS FROM AUTHORITIES

J. Stevenson-Hamilton ('54, personal communication), Warden of the Kruger National Park for 44 years and author of several books on wild life in Africa, wrote: "the females certainly carry food to their young, but there is *seldom* any large bone accumulation, as the *larger bones are apt to be chewed into small fragments and these may be also swallowed* to a considerable extent." In his book, *Animal Life in Africa* ('12), he states that "They will eat anything but *flesh of their own kind.*" This spontaneous denial of hyaena cannibalism by so outstanding an authority is particularly valuable because Dean Buckland's hypothesis demands the belief that the most outstanding characteristic of hyaenas is cannibalism.

C. D. Maguire, the celebrated Australian soldier, settler and game hunter, and father of one of my friends, who has lived on the farms Portugal and Spain in the vicinity of the Makapansgat Limeworks, and in Potgietersrust itself for the past 40 years and more, and has killed 8 brown hyaenas and 40 odd leopards during that time in the district, has inspected during that period many caves, fissures and holes in and around the vicinity of Makapansgat and Potgietersrust that had been inhabited by hyaenas; but he *has never found a single one which was stocked with bones.* He has repeatedly stated to me that they, like other wild animals, are naturally clean in their habits especially where they sleep and have their young. This denial of filthy habits was also most valuable because a second imperative in Buckland's hyaena hypothesis was that their droppings formed the album graecum characteristic of European Pleistocene bone accumulations in caves.

C. T. Astley-Maberley, outstanding wild-life artist and author, who has devoted very many years to the study of animals in their wild state in the Kruger National Park, informed me that he was shown a hole in the ground occupied

by *H. brunnea* near the Sabi river at Skukuza in the Kruger National Park, and that *the ground about was littered with bones* of impala and their skulls; but he could not say definitely whether the bones had been brought there by the hyaenas in question or not.

C. V. P. Ionides, Senior Games Ranger, Tanganyika Territory, wrote: "*I have not known the spotted hyaena to use caves or earths except when breeding*, though in N. Darfur of the Sudan both spotted and striped hyaenas could be found in large numbers in caves. I do not know whether they take meat or bones to their caves other than to feed their young. *Normally they eat it on the spot*, though they sometimes take a limb some distance to feed on it. *I should doubt whether a hyaena could accumulate bones* unless it were for the purpose of feeding its young or to afford more leisure for feeding in seclusion. They breed in the dry season." This restriction of the habitation of holes or shelters by hyaenas to the females and to the time of breeding was also very different from the hypothesis put forward by Buckland.

S. C. Schoeman, hunter and traveller in Southern Africa, writes "*I have never come across any proof to substantiate that the spotted hyaena is a collector of bones.*" He continues "The grey (brown) hyaena is very common in South West Africa and the southern half of Angola. It either lives in caves and semi-caves and holes in the ground. It is even less daring than the spotted hyaena and *I have never heard of its attacking humans or sheep or poultry.*" This was even more shocking because Buckland had believed that they followed armies and even repelled lions from their prey; and various statements are found in the literature about their audaciously attacking sleeping natives.

Mr. Schoeman, however, is the only one of my informants who asserts "the hyaena definitely collects bones, skins and anything smelling or relating to skins and bones in caves inhabited by these animals. The following articles have been found: axe and pick with handles repaired with raw hide; thick bones, pieces of skin, jukskei and other articles of similar

nature. This was observed in the Karasberg Mountains of South West Africa. It should be noted that all the farms, although very large in size, are inhabited in this area, and that the collecting of bones etc., by the hyaena may have been forced on it rather than being a natural habit. My personal opinion is that the grey (brown) hyaena being a very cowardly animal snaps up anything considered by him as edible around the farmsteads and when disturbed hurries off to its lair — there to devour it at its leisure. In the Namib area in the North West of S. W. A. I came across many of these animals — here they prefer to live in burrows, perhaps due to the absence of suitable caves. *An occasional bleached bone can be found around these burrows.* Nobody of whom I know has endeavoured to open up these burrows in order to discover its contents. A nasty stench together with the presence of hundreds of flies around the entrance indicates that bones and carrion might be present in the burrows.”

P. W. Willis, wild-life photographer and traveller wrote “one morning at grey dawn I saw an old hyaena approach a pan of water with a mouthful of bone and putrid flesh and dump this into the water presumably to keep it away from the vultures, and on another occasion I saw one approach a pan of water with a mass of lungs in its mouth. Every time it tried to put this under water the lungs floated and the animal repeatedly tried to get it to stay submerged and *at least went off with it and probably buried it in the sand.* In my 53 years experience in the low veld, both in the Eastern Transvaal and Portuguese East Africa, only once have I found where hyaenas have enlarged an antbear hole where they pupped down. This was in 1903 near what is now known as Gudzana some few miles north of Satara, before it was a reserve. On an open piece of ground, all grass and scrub cleared, I found an antbear hole *with scores of bones lying round it*, scattered over about a circle of 50 yards, bones of all sorts of which all meat had been eaten off and nothing but hard dry bones left, there were several shin and thigh bones of big game

such as waterbuck, sable, kudu and zebra lying about, all of which had been crunched up and all marrow eaten."

M. Rowland-Jones, Ranger of Punda Maria in the Kruger National Park, writes "*I have never found an accumulation of bones in hyaenas breeding holes nor do I think it likely that such is the case. After all, to a great extent they feed on bones which they chew up. Bits of hair of the animals they kill can be found round the breeding den.*"

EXAMINATION OF LAIRS

In view of these accounts, most of which were directly opposed to Dean Buckland's hypothesis, and the views about hyaenas conflicting with their habits as set forth in zoological literature and particularly in view of the lack of information we could get about the bone heaps they were supposed by paleontologists to accumulate in their dens, and which we wanted for comparison with the Makapansgat material, permission was sought of the Kruger National Park authorities to investigate the habits and behavior of hyaenas there and to excavate one or more hyaena "lairs" in the Park to examine and bring away their bone contents. The Park authorities hesitated, at the time, about our pursuing our investigations in the Kruger National Park, but kindly directed our attention to a farm contiguous with its borders, where they understood that hyaenas were more plentiful than in the Park itself. I therefore corresponded at their suggestion with Mr. U. A. Campbell who very kindly invited us to his father's (Mr. W. A. Campbell's) farm *Malamala*. There, during the first two weeks of August, 1953, my colleague, Mr. H. N. F. Harington, and I were able to make observations in the hyaena sites and to excavate one of these hyaena "lairs" with the very generous assistance of Mr. W. A. Campbell himself, who gladly shared with us his vast store of knowledge not only of this district, with which he has been associated since 1927 but also of hyaena "lairs," with which he has had much direct experience.

The farm *Malamala*, Pilgrims Rest district, Transvaal, is situated on the Kruger National Park border 16 miles north of Skukuza. The Sand River passes through the farm (fig. 2) and forms a source of water for game which cross over from the Kruger Park because the farm is continuous with the Park and not even a fence marks their respective boundaries. It has been estimated by the District Cattle Inspector that as many as 4000 head of wildebeest have been seen at one time drinking from a pool in the Sand River, a sight few if any visitors enjoy in the Park. Thus it was our privilege to observe game in large numbers and to carry out our investigation under the most favourable conditions possible.

The very day before our arrival at *Malamala*, hyaena tracks had been observed coming from one of a number of antbear holes (see fig. 1) well known as a locality infested by them. As it was estimated from the tracks that at least half a dozen animals were present, and in the belief that these holes intercommunicated underground an attempt had actually been made the day before we arrived to smoke them out with the result that a number of the holes had been filled in. This recent intrusion on their territory had not, however, dislodged the hyaenas.

Owing to the fact that the animals themselves were not seen at the "lair" it was not possible to discover whether they were of the spotted variety.

On our arrival at the site the area was covered with hyaena pad marks and one hole, larger than the rest and undisturbed by the aforesaid raid, appeared from the footmarks and aroma to have been the one most used by the hyaenas as a "lair." This hole we decided to excavate completely. The stages in excavation are figured in figures 1 and 3. Figure 4 shows the appearance of the bush country at the site of the excavation. Part of the dump of earth removed is seen in the background, and the game and hyaena paths are visible in the foreground.

Figure 1 is a plan of the area riddled with antbear holes, in which the one most obvious as having served as a hyaena "lair" was excavated. The disposition of its entrance and

tunnel system relative to the other holes is shown. Nine ant-bear holes are figured, 6 being within an area approximately 36×12 feet which includes the hole excavated. The one excavated did not intercommunicate with the others. This region



Fig. 1 Plan of antbear tunnels excavated at *Malamala*, Pilgrims Rest district, Eastern Transvaal, showing path-ways (broken lines) used by game and hyaenas between bush and trees. The trampled area used by hyaenas for lying up during the day is around the 6 holes figured together next to the excavated "lair." Tunnels average one foot three inches wide by one foot six inches high. Tunnel branches are shown on right and indicated by letters a, b, c, d. The 4 bone fragments and one faecal evacuation are indicated by the letters X = bone, Y = droppings. Trees \uparrow . Bush \circ .

had been so trampled down by the hyaenas that it was relatively clear of grass and small bush. Game paths and those used by hyaenas are indicated between broken lines in figure 1 and communicate with 8 of the 9 holes indicated on the plan.

Digging took our two natives 4 days to open completely the tunnel and its branches, which covered a total surface area of 44×16 feet approximately. The roof of the tunnel varied

in distance from one foot 6 inches to 6 feet below the surface of the ground.

The entrance (see fig. 3, upper left and lower left) to the tunnel system descended rapidly for some 3 to 4 feet before levelling out and thereafter maintained an average depth of 2



Fig. 2 The Sand River passes through typical bush country of the region. This is a view of the dry river bed looking southwards from the only prominent granite kopjie about 16 miles north of Skukuza and 20 miles east of Bushbuckridge; it looks down also towards the house and camp on the river bank on Mr. W. A. Campbell's farm *Malamala* on the boundary of the Kruger National Park Game Reserve.

to 3 feet below the surface except at the west end (vide fig. 1) where it descended to a depth of 6 feet below ground level. The tunnel ramifications except at the junction of the passages (fig. 3, upper right, lower left and right) maintained an average width of 15 inches and a height of 18 inches, abruptly tapering to an end at the extremities. Hyaenas had apparently occupied the passages (a) and (d) (see fig. 1) but there was

no indication that they had penetrated further than 8 feet from the entrance.

The floor of the tunnel where the hyaenas and their cubs had been lying was damp with urine and had the rank odor characteristic of hyaenas. Probably even this fouling of the



Fig. 3 Stages in the excavation of the hyaena lair.

- 1 *Upper left*: The entrance, about 30 inches by 15 inches, as it appeared before excavation with foot rule in foreground. Hyaena pad marks are visible as well as the marks of shoes and human feet on the surrounding ground.
- 2 *Upper right and*
- 3 *lower left*: Stages in the excavation showing tunnel depth, about 24 inches to 36 inches below surface, and branches.
- 4 *Lower right*: Same portion of excavation as in upper right and lower left but with tunnels completely uncovered.

place was the work of the pups and not of the adults. This odor we were to become even better acquainted with later when Mr. W. A. Campbell shot a spotted hyaena for us; its skeleton is now assembled in the Anatomy Department Museum. As it would be impossible for a large hyaena to turn



Fig. 4 Typical appearance of the open bush country in the region where the antbear tunnels forming a hyaena lair was excavated. In the background behind the standing native is part of the dump of earth removed by excavating the "lair."

round in the narrow passages, use was apparently made of the widened areas at the junctions only.

It is highly probable that this "lair" was occupied by no more than one or two female hyaenas with their pups at one time, the females merely entering to feed their young with their milk and with disgorged, partly digested, fragments such as lungs from a lion kill.

Except for numerous fleas, hyaena hairs and the undamaged carapace of a tortoise, the tunnels were absolutely clean and

entirely devoid of bones, faeces (*album graecum*) or other debris. It was apparently at the junctions of passages (a) and (b) and of (d) and (c) that they had their pups, for it was there that they had left their hair and the ground was wet with urine. At the junction of (c) and (d) also the intact tortoise shell was found, about 8 feet from the entrance. We found a number of similar tortoise carapaces on the veld at *Malamala* during our investigations. All the tortoises appeared to have died of natural causes because although these shells were in different stages of disintegration, all the parts of the skeleton found were intact (fig. 5).

On the ground in the grass around the holes were scratched-out hollows where the hyaenas, probably those without pups. or the females when desirous of being free from them had lain up during the day. In these hollows the hyaenas had also left hair from their coats, but no areas dampened with urine as evidence of their presence.

The ground surrounding the holes, an area of more than 130×100 feet, was carefully inspected for every possible sign of their occupation, but beyond 4 small bone fragments,

Fig. 5 Specimens found within a radius of 20 yards of the hyaena lair and sunning area in the vicinity of the exfoliated granite outcrop on the bank of a small annual stream.

- 1 *Upper left*: Two hyaena evacuations found about two yards from one another and approximately 5 yards from the "lair" figured in plate 5.
- 2 *Lower center*: The right body and ramus of a ? impala mandible—the angle of the jaw is broken off and the anterior portion missing from the diastema forwards—and the atlas vertebra of an impala, the posterior spines of whose transverse processes are damaged. These bones were found 10 yards from the lair.
- 3 *Lower right*: The distal half of the left femur of a young zebra (the distal epiphysis was broken off but is present and slightly broken; the proximal end of the bone may have been broken to remove the marrow) and the right metatarsal of an impala found in the stream bed 20 yards from the "lair."
- 4 *Lower left*: The bones of the left hind limb of a ? wildebeest complete from metatarsal to tibia were found scattered about. The tibia was broken probably to remove the marrow but its proximal half is missing. These bones were found not far from.
- 5 *Upper right*: The fragments of an almost complete though disintegrating skeleton of a tortoise about 15 yards from the "lair" and on the granite out in the open above the stream.

one evacuation of hyaena droppings and two shells of the land snail *Acatina linteris*, the entire surface area surrounding these actual and potential "lair" produced nothing unusual whatsoever. The approximate positions where the separate 4 bone fragments lay are indicated in figure 1 by the letters X, and the one evacuation of hyaena droppings by the letter Y.

The area surrounding the "lair" was in fact typical of any other part of the *Malamala* veld, where animal droppings

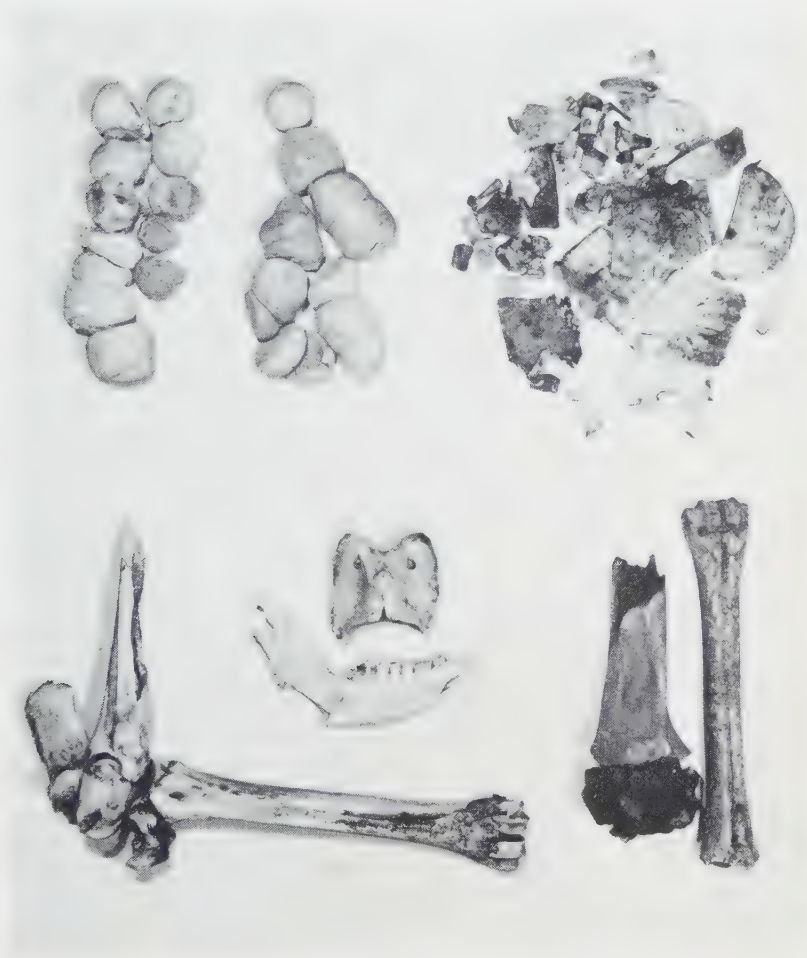


Figure 5

and a few odd bones can usually be found during a similar careful search over a correspondingly wide area. Except for the odor of urine, the foot marks and the trampled and hollowed areas where the hyaenas had been accustomed to rest, and where some of the hair from their coats left tangible evidence of their recent presence, there was nothing to indicate that they had even occupied the place.

Before occupation by hyaenas as Mr. W. A. Campbell informed me, these holes had been used by warthogs but had originally been tunnelled out of the friable, weathered-granite sub-soil by antbears (see also Miller, '50).

During the night after the digging had been started the hyaenas returned to the site, as their foot-marks showed; even on the second night they walked through the opened tunnels; but after that night they apparently did not return to the site. Their repeated return, despite the violence of our damage to their home is an index of the degree of their attachment to this particular "lair."

At *Malamala* the hyaena is frequently on the move following the activities of the lions, lying up on granite outcrops or in the bush during the day and hunting for food at night. One such granite outcrop was also found and investigated but we did not discover what variety of hyaena used it. The sheltered space below the rocky overhang was excavated at its entrance and searched carefully for bones and other debris but here also without result in the form either of shattered bones or of hyaena droppings. Careful search of the surrounding rock and ground surface within a radius of 20 yards produced a disintegrating tortoise skeleton, two hyaena faecal evacuations and a few broken bones (fig. 5); but the closest that any of these approached the rock shelter was about 5 yards. The droppings do not appear to be very different from those found in the area surrounding the excavated lair.

The failure to find any vestige of faecal droppings (album graecum) in the lairs, not even that of pups, which are several months old before they are taken into the veld by their parents (Miller, '50), is not only a corroboration of Maguire's

observations relative to the cleanly habits of hyaenas but is also in direct opposition to Buckland's assumption that the album graecum found in European cavern bone accumulations of Pleistocene times can be regarded as the coprolites of hyaenas. The coprolites found in European Pleistocene cave deposits are presumably the coprolites of the carnivorous human beings that accumulated the bones.

The carnivorous diet of hyaenas results in droppings that dry to a white colour, but these droppings are not found in a lair or hide-out. Like most wild animals the hyaena chooses an area for defaecating other than its sleeping site and may use that area more than once (see also the impala defaecating site figured in fig. 7).

GENERAL

At *Malamala* and in the Kruger National Park the common hyaena is the spotted variety *Crocuta crocuta*. The brown hyaena *Hyaena brunnea* is much less common, and owing to this and its shy and nocturnal habits is seldom seen.

Hyaenas are credited by Mr. W. A. Campbell with taking odd bones to a site used for lying up during the day and eating them while lying in the sun, but he said, firstly, that by and large their feeding is done at the site of a lion kill, where they crack open bones and lick out the marrow; secondly, that during the breeding season a hyaena will place its cubs in a position of safety such as these lairs while hunting for food (if they are disturbed at the lair the young are removed to some other suitable site); thirdly, that although hyaenas do chase vultures away from a kill after the lions have finished feeding, they will not feed off a kill after vultures have been feeding from it unless they are desperately hungry; and fourthly, that the lion, leopard, wild dog and other carnivores kill their own game for food, and normally are particular about the choice of animals they kill and eat; but the hyaena, while essentially a scavenger, does not spend his time systematically in breaking all the bones of a kill to extract their

marrow nor in carrying them off to his lair in quantity for that purpose.

These facts are illustrated by the photograph of a wildebeest kill (fig. 6). This kill was made presumably by a lion within 500 yards of the hyaena lair we excavated and thus in a position most convenient for the recent accumulation of a pile of bones in or round about the lair.



Fig. 6 Blue wildebeest killed by lion at a spot less than 500 yards from the excavated hyaena "lair" (fig. 1). Save for the femora and humeri, all the long bones of the animal are still present and some of the skin.

The remains were photographed three days after lions, hyaenas and vultures had completed their depredations, but apart from the few splintered fragments derived from the two femora and the two humeri that had been cracked about their middles in order to drag out the marrow from their cavities, there was no destruction of a single other bone on the site. All of the bones of the skeleton were in articulation with one another or in the near vicinity of the body. Indeed much

of the skin may be left intact as in this creature, which had been picked clean of flesh and fat by the vultures.

From what observations we could make personally at *Malamala* the big long bones were cracked open, presumably by hyaenas, and teeth marks were apparent on both sides of the broken bone, the marrow having been licked out of the broken ends. The ends of some long bones are also found



Fig. 7 Impala defaecating site. Droppings are visible to the left of the native. The bones scattered over the ground are those of a single impala.

damaged by attempts to remove the cartilage. A few bone flakes are usually left on the ground where they have fallen from the big long bones during the process of being crushed to remove the marrow or of being crunched and swallowed up as in the case of the 9 fragments found with the otherwise osteologically-intact wildebeest kill figured in figure 6. These skeletal remains of two carnivore kills (cf. fig. 7) were typical of many to be found on the veld around *Malamala* and are figured here for that reason.

For days after an animal had been killed and the carcass cleaned of all but the bones, the hyaenas continued to secure food from it. At all the kills examined bones were not observed to have been moved more than a few yards from the remains of the skeleton. Scattered over the veld are the bleached skeletons of antelope and zebra and it is surprising in how nearly complete a condition skeletons are found, especially as it is evident that many of them have been lying on the ground for years.

Illustrative of this fact is the almost complete impala skeleton which we found on the veld at *Malamala* 3 to 4 miles from the site of the excavated lair and brought back as an example. These bones were spread over an area of about 10 square yards. When collected together they form the greater part of the original skeleton from which apparently merely the flesh had been abstracted by all the carnivorous creatures that had feasted from it. An impala skeleton is made up of approximately 164 separate bones. The 90 sesamoid and small bones of the limbs and tail can be discounted, since they are so easily lost by treading into the ground or by being eaten with adherent flesh; the larger bones left total 74. The bones surviving in this specimen total 58 out of the remaining 74, or nearly 80%

The bones that have been attacked seriously have almost disappeared: they have not just been split open!

Figure 7 illustrates the remains of another impala, presumably killed by a lion and eaten afterwards by hyaenas and other carnivores, scattered around an impala defaecating site. In this case many more of the bones show signs of having been cracked open and eaten up, but 36 of the larger bones are still present, i.e. approximately 50%, though some are represented only by their ends.

CONCLUSION

The following conclusions have been drawn from the statements of reputable authorities and from observations personally made by examining two hyaena lairs and excavating one

of them and by examining and collecting not only their contents but also game kills in the vicinity:

1. Cannibalism is not a characteristic of the hyaena.
2. The hyaena like other wild animals, does not foul with its faeces the places where it sleeps or where it has its young.
3. The hyaena does not habitually collect bones in prodigious quantities either in its "lair" nor in the vicinity of its lair.
4. The hyaena habitually feeds where it finds its food, and only carries away, if anything, easily digested fragments such as might form food for its young.
5. Hyaenas do not habitually spend their time cracking up bones nor in carrying them to their "lairs" for that purpose. They customarily crunch and swallow, as dogs do when they can, the bone fragments resulting from breaking up bones for their marrow. The fragments of bones resulting from such hyaena feasts are customarily to be found at or near the actual site of the kill itself and not in or near the hyaena's "lair."
6. Hyaenas probably frequent caves, earths or rock fissures only when they have their young.

ACKNOWLEDGMENTS

To Professor R. A. Dart the author not only owes the opportunity for carrying out this investigation, but wishes to express particular gratitude for his unfailing enthusiasm, encouragement and assistance in the research which was actually begun 6 years ago at the Makapansgat Limeworks, Potgietersrust.

Thanks are also due to Mr. W. A. Campbell, to whom this paper owes much, for his very generous hospitality, assistance and advice during our investigations at *Malamala*; to Mr. U. A. Campbell for making the arrangements for our visit to *Malamala*; and especially to Mr. H. N. F. Harington, who collaborated with the author at *Malamala*, for his advice and assistance there.

Finally the author would like to thank the various authorities who were kind enough to reply to his correspondence, both personally or through the press.

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THE PHYLOGENETIC IMPLICATIONS OF AFRICAN AND PALESTINIAN MANDIBLE PROFILES

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EIGHT FIGURES

The fossil human mandibular fragment recently found in a Levallois-Mousterian horizon at Haua Fteah in Cyrenaica by Dr. C. B. M. McBurney (McBurney, Trevor and Wells, '53) is said to resemble most nearly, in the cusp pattern of its third molar and its general morphology, those of the Levallois-Mousterian inhabitants of Palestine described by McCown and Keith ('39) and in particular the female individual Tabun I.

The Haua Fteah dental cusp pattern was not illustrated in the article cited; but a photograph displays the natural size of the mandibular fragment from the medial aspect. So it was possible for us from that photograph to make diagrams (see figs. 1 and 5) to compare it with other African and Palestinian lower jaws.

In text figure 1, using a common alveolar plane and the posterior margin of the ramus, the restored contours in norma lateralis of the Haua Fteah fragment (thick continuous line) have been superimposed on those of Tabun I (dotted line) and of two South African Boskop mandibles. The first of these two Boskop types, and the one most closely resembling the ramus of the Haua Fteah jaw — although it is certainly somewhat larger — is the Middle Stone Age Boskopoid specimen from Springbok Flats (light continuous line), whose discovery was announced by Broom ('29) and whose mandible was described in more detail by G. W. H. Schepers ('41). The second Boskopoid individual is a recent Hottentot

(interrupted line) from the pre-Zimbabwe cultural strata on the Bambadyanalo hill site adjacent to Mapungubwe on the Limpopo River (specimen No. K5d in the unpublished D.Sc. thesis of A. Galloway in the University of the Witwatersrand, '38). The posterior half of the contours of this recent Hottentot exponent of Boskop influence actually resembles the Haua Fteah specimen more closely than it does the Springbok



Fig. 1 Superimposition in norma lateralis on the alveolar horizontal plane and upon their posterior ramal borders of the mandibles of Haua Fteah (heavy continuous line), Springbok Flats (light continuous line), Bambadyanalo K5d (interrupted line) and Tabun I (dotted line) to display the similarity between the ramus of the lower jaw from the Haua Fteah in the Cyrenaica on the Mediterranean coast and those of two South African Boskop types: a recent Hottentot (from the Bambadyanalo site of the Zimbabwe culture at Mapungubwe on the Limpopo River) and Springbok Flats Man (from a Middle Stone Age deposit at Tuinplaats) both in the Transvaal.

Flats specimen. The Tabun I mandibular contours (see also figs. 2 and 6), however, diverge from all three of these African specimens; because in Tabun I the ramus has a different form and, as McCown and Keith (op. cit. p. 215) say, "The symphysial region is shaped as in anthropoid apes; there is no chin." The absence of a chin from human jaws is not confined to primitive human mandibles such as those of the Australopithecinae, *Sinanthropus* and Heidelberg man; it is found in some New Caledonians (Thomson, '15).

We cannot tell whether the symphyseal region of the Haua Fteah mandible from North Africa resembled, as seems more probable on this evidence, these two Boskopoid South African lower jaws and its Levallois-Mousterian Skhul, rather than its Tabun I, contemporaries in having a chin. The divergence in chin prominence between the Bambadayanalo K5d Hottentot and the Springbok Flats Boskop individual on the

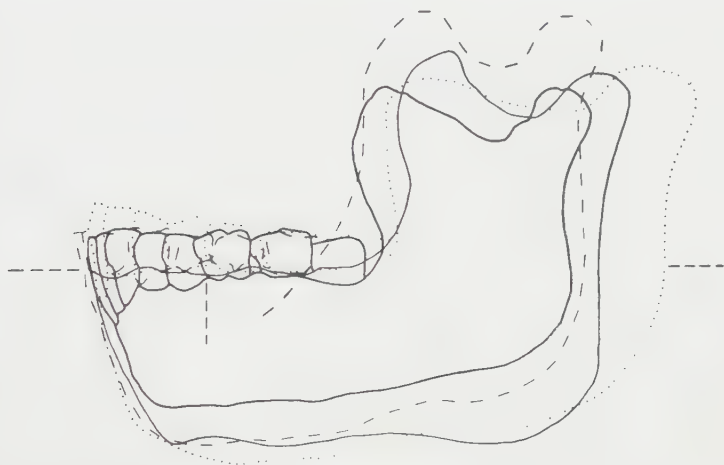


Fig. 2 Superimposition in norma lateralis on the alveolar horizontal plane and the lacteonic (anterior margin of first molar) coronal plane of the mandibles of the female Tabun I (heavy continuous line), the male *Sinanthropus pekinensis* (light continuous line), *Australopithecus prometheus* (interrupted line), and *Homo heidelbergensis* to demonstrate that the profile of the Tabun I mandible shows a closer correspondence with those of Pekin Man and *A. prometheus* than with the profile of Heidelberg Man.

one side and the relatively chinless *Australopithecinae* on the other side, however, shows that the range of chin variation in primitive humanity was as great in Southern Africa as in Palestine or elsewhere.

To illustrate the comparisons to be drawn between the bodies, rami and symphyseal contours of primitive human mandibles in figure 2, I have superimposed, on the alveolar plane and the lacteon (anterior margin of first molar) coronal plane, the Tabun I mandible (thick continuous line)

contours upon those of the adult female *Australopithecus prometheus* (discontinuous line) *Homo heidelbergensis* (dotted line) and the male *Sinanthropus pekinensis* (light continuous line).

McCown and Keith emphasized the Neanderthal affiliations of Tabun I. The remarkable fact, to my mind, which the second text figure illustrates is the similarity, almost amounting to identity, between the type of chinlessness found in the Tabun I female (heavy continuous line) and in the *Sinanthropus pekinensis* male (light continuous line). The Tabun I female lower jaw looks like that of *Sinanthropus* female; it is smaller than the *Australopithecus prometheus* female mandible but approximates it in size and appearance rather than the Heidelberg mandible, though the ramus, like those of these other primitive human beings is not so high. The presence or absence of a chin may not be a matter of great importance, but it is noteworthy that morphologically and geographically the Tabun I jaw provides a kind of mid-term between these variant southern, eastern and western mandibles of primitive man.

Figure 2 also shows that in its anterior symphysial contour the Heidelberg jaw differs to some extent from those of both Tabun I and Pekin by assuming a more nearly vertical profile. Heidelberg Man thus approximates, rather more closely than does either Tabun I or Pekin Man, other primitive human types such as the Boskop Man from Springbok Flats that were furnished with chins. In this symphysial verticality Heidelberg Man is more generalized in type than Pekin and Tabun I types and resembles the *Australopithecinae* but its very broad ramus seems to be a specialized acquisition.

The supra-alveolar height of the ramus in *A. prometheus* is greater than that found in the human mandibles we have been considering so far. A feature of interest in the Tabun II mandible, however, when oriented on the alveolar plane and compared with other primitive jaws, is that its ramus, and still more that of Skhul IV (which is just as high as those of *A. prometheus*), ascends to a somewhat greater height

than do those of Tabun I from the same site in Palestine, of Asselar from Nigeria, or of Springbok Flats from the Transvaal. I have therefore reproduced in figure 3 a similarly-oriented set of superimpositions to compare the lateral profiles of the Springbok Flats (thin continuous line) and Asselar (dotted line; vide Boule and Vallois, '32) lower jaws with

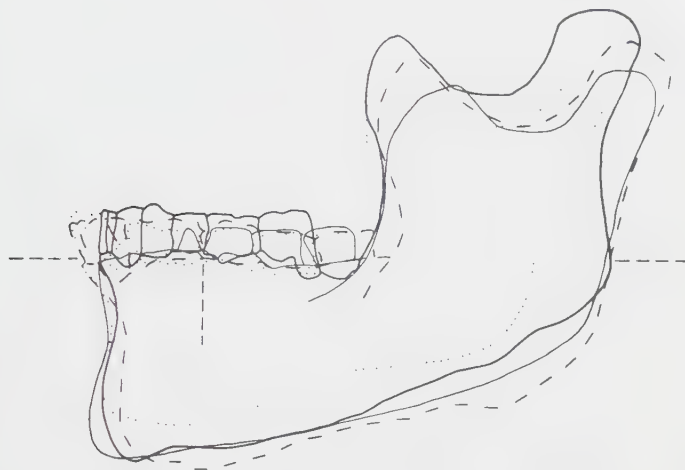


Fig. 3 Superimposition in norma lateralis on the same two planes of the mandibles of Skhul IV (heavy continuous line), Springbok Flats (light continuous line), Tabun II (interrupted line) and Asselar (dotted line) to display the comparable massiveness and form of the Skhul IV and Tabun II mandibles with the Springbok Flats Boskop specimen and the comparative Bushmanoid slenderness of the Asselar mandible from Nigeria relative to the other three from South Africa and Palestine.

those of the Tabun II specimen (discontinuous line) and Skhul IV (heavy continuous line).

This superimposition, while showing these divergences in ramal height and displaying the Bushmanoid slenderness of the Asselar specimen as compared with the Boskopoid robusticity of the Springbok Flats type reveals the comparability of the *pre-lacteonic* anatomy and symphyseal contours in these jaws as well as the proximity in size and robusticity between the Palestinian (Tabun II and Skhul IV) and Transvaal (Boskop) jaws. These Tabun II and Skhul IV Pale-

stinian mandibles are Boskopoid in type, save for their ramal height, which can be described as Rhodesioid (see fig. 4).

In figure 3 the alveolar and coronal lacteonic planes have again been superimposed; and clearly the Skhul IV and Tabun II rami differ very little from that of Springbok Flats Man save in their greater supra-alveolar height. This increased supra-alveolar height indicates that the Skhul IV and Tabun II individuals had faces that — in comparison with the equally-massive (Boskopoid) Springbok Flats and the much less massive (Bushmanoid) Asselar faces — were relatively elongated vertically. This facial feature of vertical elongation is one that Tabun II and Skhul IV shared with *A. prometheus* and Rhodesian Man as compared with Pekin and Heidelberg Man.

Figure 4 illustrates this fact by superimposing in the manner described the contours of *A. prometheus* (interrupted line) upon those of Springbok Flats (thin continuous line), Heidelberg (dotted line), and a Heidelberg mandible, whose rami were modified to enable it to articulate with the mandibular fossae of the Rhodesian skull (heavy continuous line).

Having been commissioned by the Anglo-American Corporation to make a life-size tableau of a Rhodesian Man family for display at the Rhodes Centenary Exhibition in Bulawayo during 1953, it was necessary for us as a preliminary step to reconstruct the skull and bust (see plate 1). The Mauer mandible, modified in this fashion, proved the most suitable substitute for the missing jaw. In order to adapt the Mauer mandible so that it could articulate with the Rhodesian skull the only serious alteration required was to elongate and narrow the ramus and so incidentally to reduce the overall length of the jaw. In making these alterations the Mauer jaw became progressively modified in the direction of the morphology that the mandible of *A. prometheus* subsequently exhibited (Dart, '54a, '54b) both in body length and ramal height, while the ramal width became comparable with that of Springbok Flats Man. The character of the symphyseal contour in Rhodesian Man must, of course, remain problematical until actual mandibles of the Rhodesian, or of the

nearly related Saldanha and Eyassi types have been discovered. In view of the "chinless" nature of the Mauer, Tabun I and *Sinanthropus* mandibles as well as those of the Australopithecinae and the reduction of the "chin" in the Bambadyanalo K5d and other recent human mandibles in South Africa (vide Bambadyanalo K3a in fig. 5), however,

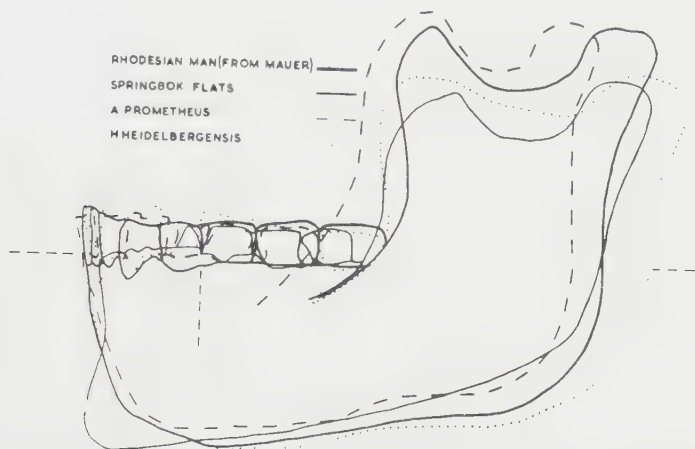


Fig. 4 Superimposition in norma lateralis on the same two planes of the mandibles of Rhodesian Man (heavy continuous line: as reconstructed from a cast of the Heidelberg jaw), Springbok Flats Man (light continuous line), *Australopithecus prometheus* (interrupted line) and Heidelberg Man (dotted line) to illustrate the modifications (shortening the jaw and lengthening and narrowing its ramus) in the direction of the promethean mandibular form in order to adapt the Heidelberg jaw to fit the Rhodesian skull. Note that the probable width of the Rhodesian ramus is similar to that of Springbok Flats and consequently to those equally massive lower jaws of Skhul and Tabun in Palestine and approximates closely that of *A. prometheus*.

it would not be surprising if the mandibles of Rhodesian, Saldanha and Eyassi Man were all "chinless." Mandibles resembling that of Mauer in all its important characters and even lacking a mental protuberance occur amongst New Caledonians and other recent men (vide Burkitt, '28). Meantime whatever its symphyseal contour characteristics, it is patent that the mandible of Rhodesian Man was approximately equivalent in length and size to that of Springbok

Flats Man and that both of these human mandibles exceeded in these respects the mandible of *A. prometheus*.

Our first text figure showed that there was greater resemblance in form between the lateral contours of the Haua Fteah and various South African Boskop mandibles with massive rami than between the Tabun I and Haua Fteah mandibles. In figure 5 the Haua Fteah fragment contours



Fig. 5 Superimposition in norma lateralis on the same two planes of the mandibles of Haua Fteah (heavy continuous line), Skhul VII (light continuous line), Bambadyanalo K5d (interrupted line) and Asselar (dotted line) to demonstrate that of the Palestinian specimens Skhul VII is the nearest in its resemblances to the Haua Fteah fragment; that the Asselar mandible resembles the Haua Fteah fragment more closely in its general form than does any Palestinian jaw: but that the Hottenot K5d from Bambadyanalo approximates it still more closely and has a symphyseal contour intermediate in type between Skhul VII and Asselar.

(heavy continuous line) have been superimposed (as nearly as possible in view of its incompleteness) on its probable lacteonic coronal plane so as to compare its appearance in this situation with the Skhul VII and the Asselar (dotted line) as well as with Bambadyanalo K5d (interrupted line) mandibles. This superimposition indicates that, although the Skhul VII ramus is much narrower, there appears to be closer similarity between the Skhul VII and Haua Fteah,

than between the Tabun I and Haua Fteah specimens. It also demonstrates

(i) that both the Nigerian Asselar and the Bambadyanalo K5d specimens are nearer in general form to the Haua Fteah mandible than is even the Skhul VII specimen, certainly nearer than is the Tabun I individual.

(ii) that the chin development of the Bambadyanalo K5d individual also is less pronounced than that of either the Skhul VII or Asselar types, and thus that Bambadyanalo K5d comes closer to Tabun I than does the Asselar type or even its contemporary fellow-countryman Skhul VII; and thus,

(iii) that the recent Bambadyanalo Hottentot K5d mandible reveals closer resemblances with the Haua Fteah mandible than does any other known mandible.

The very slight divergences between these mandibles reveals incidentally the intimacy of the comparisons that are to be drawn between human lower jaws separated by such stupendous geographical intervals as South Africa, Nigeria, Cyrenaica and Palestine, and by such a prodigious interval in time as severs the pre-Zimbabwe Hottentot culture of the Limpopo basin from the Mousterian culture of North Africa and Palestine.

Lest it be considered that this Boskopoid Hottentot K5d jaw from Bambadyanalo may be an erratic and unusual specimen there have been assembled in figure 6, and oriented upon the same planes, the lateral contours of the Tabun I (heavy continuous line) Springbok Flats (light continuous line), Bambadyanalo K5d (interrupted line) and Bambadyanalo K3a (dotted line) lower jaws. This superimposition demonstrates that, although the resemblances between the Bambadyanalo K5d and Tabun I mandibles are close, those between the somewhat more massive Bambadyanalo K3a and Tabun I are closer still in respect to the great breadth and general form of the rami and the robusticity of the body as well as the poor chin development which also approaches that of Tabun I more closely in chinlessness than does Skhul VII (see fig. 5). Yet there is no doubt from the features shared by the recent Bambadyanalo Hottentots and the Middle Stone Age indi-

vidual from Springbok Flats that the members of this Transvaal series K3a, K5d and Springbok Flats are genetically linked with one another by a common Boskopoid tradition.

Finally, to illustrate even more vividly the mandibular resemblances between African and Palestinian Middle Stone Age types, there has been superimposed on the same planes in figure 7 the profiles of the Skhul V (heavy continuous line),

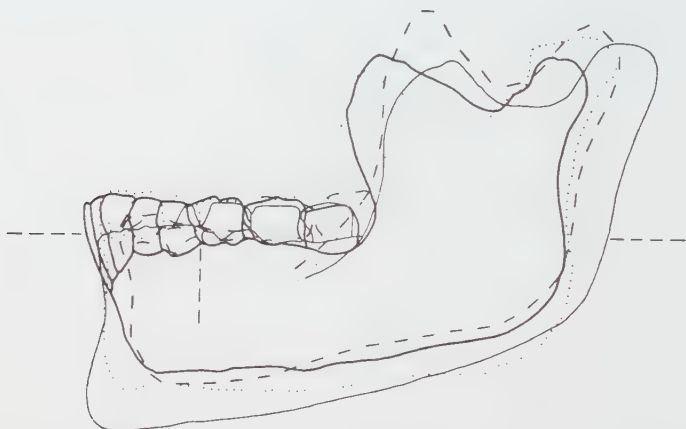


Fig. 6 Superimposition in normal lateralis on the same two planes of the mandibles of Tabun I (heavy continuous line), Springbok Flats (light continuous line), Bambadyanalo K5d (interrupted line) and Bambadyanalo K3a (dotted line), to show the even closer correspondence of K3a (than K5d) with Tabun I and the variation of the Bambadyanalo Hottentots away from the pronounced chin formation found in the Springbok Flats type and towards the chinlessness seen in Tabun I, *Sinanthropus*, Heidelberg and the Australopithecine.

Skhul IV (interrupted line), Springbok Flats (light continuous line), and our modified Mauer, or reconstructed Rhodesian (dotted line) lower jaws. By comparing figures 6 and 7 it is obvious that the rami of the two Skhul mandibles differ from the Springbok Flats ramus and resemble the Rhodesian ramus in their increased supra-alveolar height, which is exactly the same as that found in the adult female *A. prometheus* (see fig. 4). Further, in their form and verticality, these Palestinian rami approximate those of the Australo-

pitheciinae far more than do those of Mauer or Springbok Flats.

Despite this divergence in ramal form, however, the Skhul IV and Tabun II (see fig. 3) mandibles, and to a lesser degree the Skhul V mandible, rival in massiveness the Springbok Flats specimen which is the biggest known human mandible

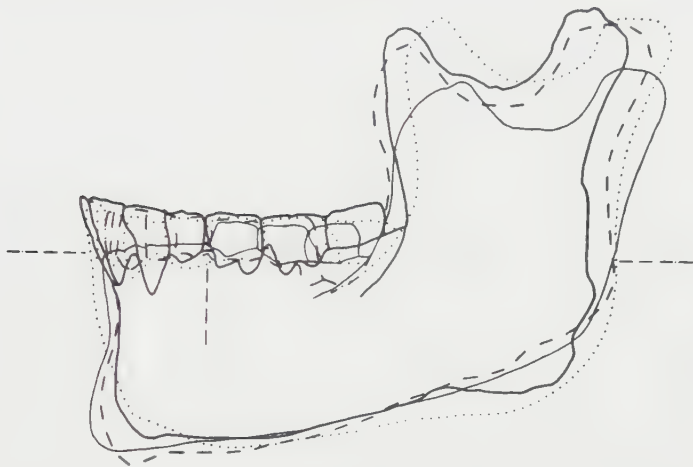


Fig. 7 Superimposition in norma lateralis on the same two planes of the mandibles of Skhul V (heavy continuous line), Springbok Flats (light continuous line), Skhul IV (interrupted line) and Rhodesian Man (dotted line reconstructed from a cast of the Heidelberg jaw) to illustrate the comparability in form and massiveness of the Skhul and Springbok Flats specimens; to show that, where they depart from the Springbok Flats type in increased ramal height and verticality, the Skhul specimens approximate more closely the australopithecine type of mandible demanded by the Rhodesian skull; and to demonstrate the comparability in symphyseal profile and size of these African and Palestinian human beings.

in South Africa, apart from the most massive australopithecine mandibles. The comparability in massiveness of these 4 mandibles (fig. 7) lends particular interest to the similarity in their symphyseal profiles. The Rhodesian profile may have been less vertical than those of Mauer and the Australopithecinae (and thus have resembled those of Tabun I and the *Sinanthropus-Pithecanthropus* group); but the divergence

between the Skhul IV and Springbok Flats symphysial and body profiles is negligible; and reduced the chin development of Skhul V is directly comparable with that seen in Bambadyanalo K5d and K3a. The Skhul IV and V mandibles are morphologically intermediate forms between those of *A. prometheus* and Springbok Flats Man.

SUMMARY

By a comparison of mandibular profiles it has been shown:

1. That the alterations in the Mauer jaw required to adapt it for articulation with the skull of *Homo rhodesiensis* entailed reducing its total length and slenderizing its ramus (by increasing its supra-alveolar height and decreasing its width); and that these artificial changes were in the direction of producing a mandible whose profile contours were more closely akin to those of the female adult *Australopithecus prometheus*.

2. That the supra-alveolar height and width of the ramus in *Australopithecus prometheus*, which is greater than that of most sapient human lower jaws is approximately the same as that found in a Heidelberg jaw that has been adapted to articulate with the cranium of *Homo rhodesiensis*, and with that found in the lower jaws of the two Palestinian skulls Skhul IV and Tabun II.

3. That the mandibles of Skhul IV and V, while having a greater supra-alveolar ramal height, resemble very closely in their massiveness and general form the lower jaw of the Boskop Man from Springbok Flats in the Transvaal; and that this resemblance between Palestinian and South African mandibles is brought even closer by a comparison of the Springbok Flats specimen with that of Tabun II.

4. That the Tabun I female mandible strongly resembles in its general form and "chinlessness" the lower jaw of *Sinanthropus*; and that the recent mandible which approximates it most closely in general form is not the Haula Fteah mandible but the Hottentot lower jaw K3a from the Pre-Zimbabwe cultural strata on Bambadyanalo Hill at Mapum-

gubwe on the Limpopo River that also yielded K5d; and that both of the Hottentot mandibles are closely affiliated to and probably derived from the Middle Stone Age Boskop type.

5. That the Haua Fteah mandibular fragment has a ramus almost identical with those of Springbok Flats and Bambadyanalo K5d; that the Haua Fteah jaw resembles Skhul VII more closely than any other Palestinian jaw; that the Haua Fteah jaw resembles the Nigerian jaw from Asselar in general form more closely than it resembles Skhul VII; and that it resembles even more closely still the Bambadyanalo K5d Hottentot mandible from the Mapungubwe site of Pre-Zimbabwe culture on the Limpopo River in the Transvaal.

6. That, since the Haua Fteah and Tabun I mandibles find closer comparisons in South African Boskop and Hottentot mandibles than with one another, Galloway's ('37b) contention, based on Boule and Vallois's ('32) analysis, is corroborated that Asselar Man is a Boskop type containing features of another (Bush) intrusive strain; and it is patent that, so far as their lower jaws and correlated facial structure are concerned, there was no great divergence between Palestinian and North and South African Middle Stone Age human types and that these in turn were not far removed from some South African female Australopithecine types of face.

In conclusion I wish to acknowledge gratefully the help of Mr. H. N. F. Harington, my Laboratory Assistant, in preparing the accompanying diagrams and Mrs. B. E. Wilson's secretarial assistance.

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PLATE

PLATE 1

EXPLANATION OF FIGURE

8 Profile and full-face views of semi- and complete reconstructions of the bust of *Homo rhodesiensis* by Mr. Edal Marcus and the author after adapting the ramus of a cast of the Mauer (*Homo heidelbergensis*) mandible to articulate with a cast of the skull.

THE DIRECTION AND POSITION OF THE MENTAL FORAMEN IN THE GREAT APES AND MAN

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Some years ago the late Professor Franz Weidenreich mentioned to me that in his experience he had observed the mental foramen in man generally opens "backwards," while in the great apes the foramen usually opens "forwards." Since few quantitative observations were available on this subject it seemed worthwhile to inquire into the facts. Fragments of this region of the skeleton of fossil man are frequently the only parts recovered. If, then, Weidenreich's observation could be established as a reliable criterion, it could prove a useful aid in the diagnosis of fragmentary remains.

An examination of standard texts with reference to the direction of opening of the mental foramen yielded several descriptions. Leidy (1889) writes, "the mental foramen . . . opens upward and outward." Augier ('31) states "le trou mentonnier, orifice de 1 a 2 mm, ouvert en haut et en arriere."

Bünthe and Moral ('10), and Schulz ('33), state that in the majority of the cases examined by them the mental foramen in man opened backwards and upwards, while in the anthropoids the foramen was directed forwards. Commenting upon these findings by these authors Weidenreich ('36) wrote that "This latter statement is not quite correct for in some cases the apertures are also directed backwards or upwards." As we shall see, if the descriptions given by these authors are not quite correct, neither is that given by Weidenreich.

In order to determine the manner in which the mental foramen opened upon the mandible, it was examined in the man-

dibles of 100 adult apes, that is, 40 gorillas, 36 orangs, and 24 chimpanzees. In addition 100 human mandibles were examined, 28 being American whites, and 72 Central Europeans, all of the male sex.

The principal purpose of this investigation was to determine the direction in which the mental foramen opened. A second purpose was to record the position of the foramen in relation to the tooth or teeth beneath which it was situated.

As the investigation proceeded it became evident that the direction of opening of the mental foramen was not limited to an anterior or posterior direction, but that the foramen frequently opened laterally, and superiorly, or in a combination of any two possible directions of opening. All these varieties of openings were recorded and their frequencies are presented in table 1. These varieties of openings may be described here. The body of the mandible rests on a horizontal plane.

VARIETIES OF OPENING OF THE MENTAL FORAMEN OCCURRING
IN THE GREAT APES AND IN MAN

- Anteriorly.* The mental foramen opens anteriorly when there is an absence of a developed margin anteriorly and the developed margin is situated posteriorly, superiorly, and inferiorly. Thus, for example, holding a probe parallel to the body of the mandible it would be possible to insert it into the mental foramen anteriorly; the developed posterior margin would prevent the possibility, at least theoretically, of the probe's insertion posteriorly. Perpendicular to the body of the mandible the superior and inferior margins would prevent entry of the probe.
- Posteriorly.* The mental foramen opens posteriorly when there is an absence of a developed margin posteriorly and the developed margin is situated anteriorly, superiorly, and inferiorly.
- Laterally.* The mental foramen opens laterally when the margin completely encircles the foramen, and the probe can only be inserted by being held at a right angle to the body of the mandible.
- Superiorly.* The mental foramen opens superiorly when there is an absence of a developed margin superiorly and the developed margin is situated inferiorly, anteriorly, and posteriorly. (It is of interest to note here that in not a single case, either among

TABLE 1
Direction of opening of the mental foramen in the great apes and man

GENUS	NO.	SEX	POSTERIORLY	ANTERIORLY	LATERALLY	ANTERIORLY AND SUPERIORLY		SUPERIORLY AND LATERALLY		POSTERIORLY AND LATERALLY		POSTERIORLY AND SUPERIORLY	
Pongo	20	♂	....	14	70.0	4	20.0	....	1	5.0	1	5.0	....
Pongo	16	♀	....	10	62.5	6	37.5	....	....	....	....	....	....
PONGO	36	♂ × ♀	....	24	66.6	10	28.0	....	1	2.8	1	2.8	....
Pan	7	♂	....	5	71.4	1	14.3	1	14.3	....	....	....	....
Pan	17	♀	1	5.9	7	41.2	5	29.3	4	24.7	....	....	....
PAN	24	♂ × ♀	1	4.2	12	50.0	6	25.0	5	20.8	....	....	....
Gorilla	24	♂	3	12.5	5	20.8	8	33.3	....	1	4.2	6	25.0
Gorilla	16	♀	5	31.3	1	6.3	4	25.0	1	6.3	2	12.3	....
GORILLA	40	♂ × ♀	8	20.0	6	15.0	12	30.0	1	2.5	3	7.5	8
HOMO	100	♂	37	37.0	12	12.00	15	15.0	1	1.0	15	15.0	....
											4	4.0	10
												6	6.0

the great apes or in man, was the opposite condition encountered, in which the margin is present superiorly but not inferiorly.)

Anteriorly and superiorly. Where the margin is wanting anteriorly and superiorly.

Posteriorly and superiorly. Where the margin is wanting posteriorly and superiorly.

Posteriorly and laterally. Where the margin is wanting posteriorly and laterally.

Laterally and superiorly. Where the margin is strongly developed inferiorly and the foramen clearly opens laterally.

In man, at least, the mental foramen may open in any one of these 8 different ways, not counting a difference, in 5 of our series, in manner of opening of the foramina on opposite sides of the same jaw.

Homo. The most frequent form of opening of the mental foramen in man in our series of 100 whites was posteriorly (37%). The next most frequent forms were laterally (15%), followed by anteriorly (12%), posteriorly and superiorly (10%), superiorly (6%), posteriorly and laterally (4%), and anteriorly and superiorly (1%).

Adding all forms of posterior opening together we obtain 51%. Thus, in man the most frequent form of opening is posteriorly: 37% wholly posteriorly, 10% posteriorly and superiorly, and 4% posteriorly and laterally.

The second most frequently occurring direction of opening is laterally, with a total of 34%. Fifteen wholly lateral, 15% laterally and superiorly, and 4% laterally and posteriorly.

The third most frequent occurring direction of opening is superiorly, with a total of 32%. Six wholly superiorly, 15% superiorly and laterally, and 10% superiorly and posteriorly, and 1% superiorly and anteriorly. It may be remarked here that the superior direction of opening in its simon-pure form is the only one which does not appear to occur in any of the great apes.

In its unmixed form the anteriorly directed foramen occurs more frequently (12%) than the unmixed superiorly directed foramen (6%), but the total of mixed anteriorly directed foramina plus the unmixed anteriorly directed for-

amina is less (17%). Warwick ('50) obtained similar results with the adult human mandible oriented in the alveolar plane. He examined the mental foramina on both sides in 69 mandibles, a total of 138 mental foramina. He reports his results in a diagram showing the approximate axis of opening of the mental foramen. From a reading of these axes it would appear that out of the total of 138 foramina 62% opened posteriorly, 26% postero-laterally, 9% superiorly, and 1.5% anteriorly.

When these figures are compared with those for the great apes it is seen that the frequencies are very different.

While in man the most frequent form of opening is posteriorly, the orang never exhibits this type in even a mixed form, the chimpanzee shows it in only 3%, and the gorilla in 18% unmixed and 4% mixed forms.

In the great apes the direction of opening of the foramen mentale is in by far the larger number of instances anteriorly in both unmixed and mixed forms, a large percentage also opening laterally.

Pongo. In the orang 67% of foramina open anteriorly, 3% antero-laterally, while 28% open laterally, and 3% open supero-laterally. That is to say in the orang 73% of mental foramina open anteriorly, 67% in unmixed and 6% in mixed forms.

Pan. In the chimpanzee 50% of foramina open anteriorly, and 21% antero-superiorly, a total of 71%. There are 25% which open laterally.

Gorilla. In the gorilla, unlike the other great apes the most frequent form of opening is laterally in 30% of cases, antero-laterally in 20%, supero-laterally in 8%, and postero-laterally in 3%, a total of 60% laterally opening types of mental foramina. The next most frequent form of foramina in the gorilla is posteriorly with 20%, with 3% in addition opening postero-laterally, and 3% opening postero-superiorly, yielding a total of 25% posteriorly opening types of mental foramina. The gorilla resembles man more closely than do any of the other great apes with respect to the most frequent

type of hominid mental foramen, namely, the posteriorly opening form. In man this occurs in 37% of cases, in the gorilla in 20% of cases. The gorilla is also more akin to man in the distribution of the other varieties of mental openings than are the other great apes.

These findings indicate that while there are significant differences in the frequencies of direction of opening of the mental foramen between man and each of the great apes, it would, on the whole, be hazardous to use the direction of opening of the mental foramen as a diagnostic aid.

In the present series the only form of mental opening which man shows which does not occur in the great apes is the superior, and this occurs in only 6% of our cases. The posterior-superior form occurred in only one gorilla (2.5%), in man in 10% of cases, and not at all in the orang and chimpanzee. The same frequencies were found for posterior-lateral openings in the great apes, in man the frequency for posterior-lateral openings being 4%. Hence, when these three types, the superiorly, the posteriorly-superiorly, and the posteriorly-laterally opening mental foramen, are encountered, it may be concluded with a high degree of probability that one is dealing with a hominid mandible. The remainder of the forms of mental opening present so much intergeneric overlapping as to render them well-nigh useless for diagnostic purposes.

THE FUNCTIONAL MEANING OF THE DIRECTION OF THE MENTAL FORAMEN

Ever since 1771 when John Hunter referred to the peculiar direction of the mental foramen in man its functional significance has been something of a puzzle. The anthropoid foramen is generally directed anteriorly and laterally, while in man it is generally directed posteriorly and superiorly. However, the gorilla exhibits all the directions of orientation of the foramen to be found in man, with the exception of the purely superiorly directed foramen, while man exhibits all the forms of opening which occur in the great apes, with the exception

of the antero-lateral opening. With this kind of variability in the great apes and in man it is of interest to inquire what the significance may be of the various directions of opening of the foramen.

Is the direction of the mental foramen of adaptive value? Or is it a neutral trait of no adaptive significance? Is it perhaps an example of the effects of genetic drift? Is the direction of the foramen in any way related to the growth, development, and functions of the jaw as a whole?

An investigation calculated to throw some light on the first questions would probably prove rewarding. It is at present not possible to answer those questions. With respect to the remaining questions Brash ('24) pointed out that the opening of the mental foramen moves backwards in relation to the teeth during the years of growth, and he likened the changes in direction of grooving to similar conditions in the growth of nutrient foramina. Recently Warwick ('50) has taken up Brash's suggestions with interesting but inconclusive results. Warwick finds that in fetuses the mental nerve is untortuous in its course, whereas in the adult it is always tortuous. Furthermore, while in the newborn the direction of the nerve corresponds to the direction of the foramen, that is, anteriorly and superiorly, in the adult the trunk of the nerve is directed posteriorly. How does this change from infant to adult come about? Warwick thinks that two factors may be involved: "First, a functional variation in the distance from the foramen of exit to the soft parts supplied by the nerve, and, secondly, a relative difference between the growth of the mandibular and alveolar parts of the bone, and therefore between the foramen and the same soft tissues" (p. 118). Warwick points out that the latter relationship is involved in the development of the chin, and that the backward inclination of the foramen occurs approximately at the time of the development of the human chin. Warwick, however, states that "the growth changes which produced a chin do not seem to provide a complete explanation of the change in direction of the fora-

men, and it is concluded that the functional factor of jaw movements is also involved" (p. 119).

That the chin is of not much help in explaining the direction of the mental foramen is borne out by the fact that both the chimpanzee and gorilla show respectively over 4% and 25% of backwardly inclined foramina.

It has often been pointed out, and most recently by Du Brul and Sicher ('53), that the mandible has been involved in the total readjustment of the skull to the upright posture, with a resulting anteroposterior shortening of the jaw. Like the bones of the cranium the gradient of growth is directed posteriorly and superiorly, and in the jaws towards orthognathly. The groove and opening of the mental foramen would seem to be most influenced in this direction in the genus of primates in which this trend is most marked. Indeed, among the primates the mandible of *Homo* would appear almost to exaggerate the trend toward the posterior and vertical disposition of growth.

MULTIPLE FORAMINA

There are few observations on the mental foramen in fossil man. Weidenreich ('36) points out that on the right side of the Heidelberg mandible there are three mental foramina, and on the left side only two. In *Sinanthropus* the mental foramina vary between two to 5 in number and open in all directions. Weidenreich ('36) writes, "It is not quite correct to speak of a foramen mentale in *Sinanthropus* because none of the specimens preserved show just one single foramen. The multiplicity of this aperture is a rather striking characteristic feature of *Sinanthropus*."

In referring to the records of fossil man Warwick ('50) found that two or more mental foramina were present in those forms in which the chin was either wanting or ill developed, but represented by a single foramen in those forms which presented a prominent chin. In the mandibles of fossil children the multiple foramina were directed superiorly and

anteriorly, but in the fossil adults a posterior one was often directed superiorly and posteriorly. As Warwick points out, the condition of the mental foramen in fossil jaws is often too poor to make out its original orientation with any degree of security. Warwick promises to report more fully upon the fossil material at a later date.

TABLE 2

Multiple foramina in the great apes and in man

	SIDES EXAMINED	CASES OF MULTIPLE FORAMINA	
		No.	Per cent
Orang (Simonton)	123	48	(39.0)
Gorilla (Simonton)	43	12	(27.8)
Chimpanzee (Simonton)	32	5	(15.6)
Negroes (Simonton)	42	7	(16.7)
Melanesian (Simonton)	58	6	(10.3)
Eskimos (Simonton)	114	10	(8.8)
American Whites (Simonton)	138	9	(6.5)
Kentucky Indians (Simonton)	150	8	(5.3)
Arkansas Indians (Simonton)	108	5	(4.6)
Japanese (Hori)	682	28	(4.1)
Japanese (Akabori)	682	23	(3.4)
Central European (Montagu)	150	4	(2.7)
Italian (Bertelli)	400	11	(2.6)
French (Le Double)	800	21	(2.6)
California Indians (Simonton)	342	8	(2.3)
American Whites (Montagu)	56	1	(1.8)
Russians (Gruber)	2400	35	(1.5)
Egyptians (Simonton)	156	0	(0.0)

Multiple mental foramina occur with the highest frequencies in the great apes. They also occur in varying frequencies in different living ethnic groups of man, as may be seen in table 2.

By far the largest frequency (39%) of multiple mental foramina occurs in the orang. In a group of orangs which come from the same district the pattern or arrangement of the multiple foramina is astonishingly similar in different individuals. Five or more foramina being a highly frequent number on each side of the mandible. The second highest

frequency occurs in the gorilla (29%), and the third highest in the chimpanzee (16%), a frequency which, according to Simonton's ('23) observations, is higher in the Negro (17%). Indeed, among the living varieties of men the Afroamerican and the Oceanic Negroids show the highest frequencies of multiple foramina.

All observers agree that multiple foramina are slightly more frequent on the right than on the left side (Akabori, '34; Bertelli, 1892; Gruber, 1872; Hori, '27; Le Double, '06). The most frequent number of multiple foramina in man is two, although as many as 5 on each side have been recorded in recent man (Senyürek, '46).

Akabori ('34) interprets multiple foramina to be "clearly an evidence of primitivity," and remarks, "We see in the table above that the Japanese occupies a position less primitive than Whites in general," adding "But it is remarkable that in the Russian the frequency is exceedingly low."

It is of interest to note that the African and Oceanic Negroids show the highest frequencies of multiple foramina, while there were no multiple foramina in the Egyptian series examined by Simonton ('23), and Gruber's (1872) Russians showed but 1.5%. Clearly, the variability in frequency of multiple foramina encountered in the ethnic groups of man is a genetic trait which would repay further investigation.

With respect to sexual variation Hori ('27) in his Japanese series found that multiple foramina were more frequent in females (15%) than in males (5.0%). On the other hand, Akabori ('34) in his Japanese series found absolutely no sexual difference in the frequency of mental foramina.

In European whites two mental foramina on one or both sides occur in about 2.7% of cases. The occurrence of three mental foramina on one or both sides is extremely rare in man, Bertelli (1892) finding this frequency of foramina in 100 Italian mandibles in only one instance, Gruber (1872) in 1200 Russian mandibles finding it in only one instance, and Le Double ('06) in 400 French mandibles finding it in only one instance, a total of three cases out of 1700 European mandibles

or in 0.17%. Akabori ('34) in 341 Japanese mandibles found triple mental foramina 4 times, three times on the right and once on the left side, but he does not state whether these were unilateral or bilateral cases, although from a table which he gives (p. 303) it would appear that 4 separate mandibles were involved, and that, hence, these triple mental foramina were represented only unilaterally, a frequency of 1.1% in Akabori's Japanese.

THE POSITION OF THE MENTAL FORAMEN

There has been some confusion concerning the usual position of the mental foramen. Thus, Holden (1878) found the foramen to be "generally in line with the *first* pre-molar tooth," (p. 108). Allen (1882) placed the mental foramen "opposite and below the interspace between the second molar and the first bicuspid," (p. 139). Leidy (1889) found the foramen to be "commonly a little over an inch from the symphysis, and nearer the base than the upper border" (p. 130). Humphry (1858) stated that "The *Mental foramen* is generally placed beneath the interval between the two bicuspid teeth, in a vertical line with the supra-and infra-orbital foramina, or very nearly so. It is situated further back in the Negro, beneath the second bicuspid, or beneath the interval between it and the first molar" (p. 290).

Morris's Human Anatomy ('42) states that the mental foramen is to be found in the interval "between the premolar teeth" (p. 106), but some 60 pages later situates the foramen "opposite the second bicuspid tooth" (p. 165). Cameron ('34) states that the usual position of the mental foramen is "about midway between the two borders, and either opposite the interval between the premolar teeth, or very slightly in front or behind" (p. 121). Gray's Anatomy ('42) puts the mental foramen "beneath the second premolar tooth" (p. 132, 143). Gerrish's Anatomy ('02) says "midway between the upper and lower borders and in line with the second bicuspid tooth, or the interval between the two bicuspid, is the mental foramen" (p. 200). Piersol's Anatomy ('30) puts the mental

foramen "rather below the middle of the bone under the second bicuspid, sometimes just below it" (p. 211). Dixon-Jamieson ('37) state that the mental foramen is situated "about an inch from the symphysis, below the socket of the *second* premolar tooth. If the sockets are present, the foramen is midway between the upper and lower borders of the bone; but it is near the upper border if the walls of the sockets have been absorbed" (p. 387). Cunningham's Anatomy ('43) describes the mental foramen as situated "below the second premolar or the interval between the premolars" (p. 190). Grant ('48) situates the mental foramen " $1\frac{1}{4}$ inches from the symphysis, in line between the bicuspid teeth, and midway between the lower border of the jaw and the alveolar border" (p. 682).

Evidently the authorities do not quite agree.

Tebo and Telford ('50) in 100 unselected, unsexed mandibles found the relationship of the mental foramen to the teeth to be as follows:

- (1) Foramen anterior to the lower first bicuspid tooth:
right, none, left, none;
- (2) Foramen at the apex of the lower first bicuspid tooth:
right, 2.3%, left, 1.2%;
- (3) Foramen between the apices of the lower bicuspid teeth: right, 25.3%, left, 20.7%;
- (4) Foramen at the apex of the second bicuspid tooth:
right, 46.0%, left, 52.8%;
- (5) Foramen posterior to the second bicuspid tooth: right, 24.1%, left, 24.1%;
- (6) Foramen below the root apices of the first molar:
right, 2.3%, left, 1.2%.

Clearly, the most frequent relationship of the mental foramen to the apices of the teeth in this series of mandibles was to the apex of the second premolar, 46.0% on the right and 52.8% on the left.

Miller ('53) in a series of 75 Hindu mandibles (estimated ages 20 to 45 years) found the mental foramen to be located below the apex of the first premolar in 3%, between first and

second premolars in 38%, below the apex of the second premolar in 40%, and between the second premolar and the first molar in 20%. These findings are in good agreement with those of Tebo and Telford ('50).

I recorded the position of the mental foramen in the 100 adult great apes and in the 100 Caucasoid mandibles already referred to in the present paper. The findings are set out in table 3. From the percentages listed in table 3 for the great

TABLE 3

The mental foramen in relation to the apices of the teeth

GENUS	NUMBER OF MANDIBLES	SEX	FORAMEN MENTALE SITUATED BENEATH				
			PM1	PM1 & 2	PM2	PM2 & M1	M1
			%	%	%	%	%
Pongo	20	♂	20.0	15.0	60.0	5.0	...
Pongo	16	♀	25.0	31.2	31.2	12.5	...
PONGO	36	♂ × ♀	22.2	22.2	47.2	8.3	...
Pan	7	♂	...	28.6	43.0	14.3	14.3
Pan	17	♀	...	30.0	47.0	23.5	...
PAN	24	♂ × ♀	...	29.2	45.8	20.8	4.2
Gorilla	24	♂	8.3	29.2	58.3	...	4.2
Gorilla	16	♀	37.5	25.0	31.2	6.2	...
GORILLA	40	♂ × ♀	20.0	27.5	47.5	2.5	2.5
HOMO	100	♂	12.0	22.0	63.0	3.0	...

apes and for the Caucasoid mandibles it will be seen that they are in pretty close agreement with those of Tebo and Telford ('50). In the great apes as in man the most frequent relationship of the mental foramen in the adult is to the apex of the second mandibular premolar.

Practically all observers agree that the mental foramen is situated about halfway between the base and the alveolar borders of the mandible, and Tebo and Telford ('50) found it to lie approximately one-fourth of the distance from the symphysis menti to the posterior border of the ramus.

I owe thanks to Dr. Remington Kellogg, Director of the U. S. National Museum, Washington, D. C., for permission to examine the anthropoid mandibles, and to Mrs. E. Wade, Curator of the Museum of the Philadelphia College of Physicians, for permission to examine the Central European mandibles.

SUMMARY

1. The direction of opening of the mental foramen is described in 100 adult great apes and in 100 whites.

2. In the orang and chimpanzee the direction of opening of the mental foramen is most frequently anteriorly, 77% in the orang and 70% in the chimpanzee, whereas in the gorilla the most frequent direction of opening is laterally — in 52% of the cases, with 44% opening anteriorly.

3. In man the most frequent form of opening is posteriorly in 51%. It is of interest to note that the posterior opening does not occur in the orang, in only 4% of cases in the chimpanzee, and in the gorilla in 20% unmixed and 5% mixed forms.

4. In man the lateral opening of the mental foramen occurs next most frequently with a total of 34% in all its mixed forms, and in 32% the opening is superiorly in all its mixed forms, the purely superior opening occurring in only 6% of cases. The purely superior opening does not occur at all in our series of great apes.

5. It is shown that the superiorly, the posteriorly-superiorly, and posteriorly-laterally opening mental foramina occur so rarely in the great apes that when these types of foramina are encountered in a fragmentary mandible one may conclude with a high degree of reliability that it is of hominid origin. The remainder of the forms of mental opening present so much intergeneric overlapping as to render them well-nigh useless for diagnostic purposes.

6. Multiple mental foramina occur most frequently in the orang (39%); in the gorilla (28%), and in the chimpanzee (16%).

7. In European whites two mental foramina on one or both sides occur in about 2.7% of cases, and three mental

foramina in about 0.17% of cases. As many as 5 mental foramina have been recorded in man.

8. The most usual position of the mental foramen is midway between the base and alveolar process of the mandible below the apex of the second premolar, one-fourth of the distance from the symphysis menti to the posterior border of the ramus.

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METAMORPHOSIS OF THE JOINTS OF THE STERNUM IN RELATION TO AGE CHANGES IN OTHER BONES

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FOUR FIGURES

Through his work on the pubic symphysis, Todd ('20) established the concept that "certain bone areas adjacent to joints show definite sequence of modification strictly associated with age" (p. 287). Speaking of the symphysis specifically, he stated that "from the eighteenth year onward, the changes undergone by the pubis are largely if not entirely a metamorphosis and not an actual growth" (p. 325). Unfortunately, however, he did not pursue this subject much beyond the symphysis, at least as regards the late-maturing joints of the postcranial skeleton. Indeed, his summary of the possibilities of finding skeletal age markers, which appears in the introduction to his study of the symphysis ('20, pp. 287-288), indicates that he regarded similar studies of certain other joints, and especially those of the sternum, as rather unpromising. Part of this statement is worth quoting, nevertheless, because it summarizes joint metamorphosis in a masterly way:

In the main this group [of joints yielding a sequence of modification associated with age] consists of amphiarthroses, namely the symphysis pubis, the intercentral joints of the vertebral column, and the manubrio-gladiolar articulation. But to these must also be added the sterno-clavicular, sacro-iliac and possibly the costo-chondral and chondro-sternal joints. The plane between the bone and the articular cartilage of these joints displays features resembling in some degree those of the diaphyso-epiphysial plane, and it is upon this fact that the age changes resolve themselves. Adjacent to these joints "articular" epiph-

yse ossify incompletely, erratically or not at all. Of the series the sterno-clavicular area early removes itself from consideration through the fusion of the epiphysis at the sternal end of the clavicle with the shaft of the bone, while the manubrio-gladiolar articulation is so erratic as apparently to warrant no confidence. The intercentral joints of the vertebral column, and the pelvic articulation areas, on the other hand, are most important. Even after the last stragglers among the epiphyses, namely those of the spines and transverse processes of the vertebrae, the heads of the ribs, and the sternal end of the clavicle, have lost their identity through fusion, the line of union of the central epiphyses shows distinct independence from the vertebral body. And when the second of these also at last, in the early thirties, fails to register the individual's age, the symphysis pubis still retains its role of time marker. Indeed, the symphysis tells its tale throughout life, although less clearly from forty years onward than at an earlier age.

I do not believe that Todd intended these remarks to discourage others from doing research along the same lines on the joints of the sternum; I think he was only justifying his own course of action by reporting a widely-held belief which he had not bothered to check adequately. After all, he may have been well aware that back in 1890 Thomas Dwight, Professor of Anatomy at Harvard, had expressed the opinion that "the sternum is of little value as an index of age" (p. 532). The fact remains, however, that today, a quarter of a century after Todd studied the pubic symphysis, we still cannot read with any confidence the signs of ageing displayed in the joints of the sternum. Also, the need has existed all this time for other criteria by which to assess the age of skeletons which have damaged or missing pelvises.

Further accounting for the long-standing neglect of age changes in the sternum is unnecessary here. I will say simply that when recently I was offered the opportunity to observe (at a future date) age changes in skeletons of fully identified young adult males, I decided to extend my observations to the unstudied joints mentioned by Todd in the above quotation. This decision necessitated an examination of the features in question so as to determine what is significant for recording

purposes. Having at hand only skeletons from archeological sources, I could evaluate the observed sequence of bone modification in each joint area only in terms of known age changes in other parts of the same skeletons, particularly tooth eruption, epiphyseal union, symphyseal metamorphosis and suture closure. Since study of the sternum has proved to be surprisingly rewarding, and since all observations of this nature are useful in skeletal identifications, I feel that my findings on this bone are worth reporting in advance of the opportunity for securing more exact dating. (See addendum, p. 528.)

ANATOMY OF THE STERNAL JOINTS

The sternum is unique in the number and types of its articulations. In addition to the manubriogladiolar or superior intersternal joint, which in most cases is a synchondrosis (fig. 1),¹ there are a pair of sternoclavicular joints (type: diarthrosis), and usually 7 pairs of chondrosternal joints (types: first pair are synchondroses; all others diarthroses). The inferior intersternal joint, that between the corpus of the sternum and the xiphoid process, may be ignored for present purposes. This makes a total of 17 joint areas the metamorphosis of which may be expected to provide age markers. In this connection it is noteworthy that on each side the joints for the clavicle and first rib, which differ in type (see above), are contiguous, whereas the joint for the second rib is located at the junction of the manubrium and corpus and hence in close relationship with the superior intersternal joint (again 2 joints of different type in juxtaposition). Such relationships require that these two joint complexes be considered as units from the standpoint of modification with age. In addition, since the superior elements of the corpus may not fuse until early in the third decade, and the joint for the third rib is located at the

¹ Gray's anatomy cites Rivington and Maisonneuve as authorities for the statement that this joint is diarthrodial in one-third or more of adults, being formed in these cases perhaps by absorption from the original synchondrodial (amphiarthrodial) form.

line of union, the metamorphosis of the third chondrosternal joint probably reflects the local rate of ossification.

Todd was correct in stating (see above quotation) that "The plane between the bone and the articular cartilage of these joints displays features resembling in some degree those of the diaphyso-epiphyseal plane; and it is upon this fact that the age

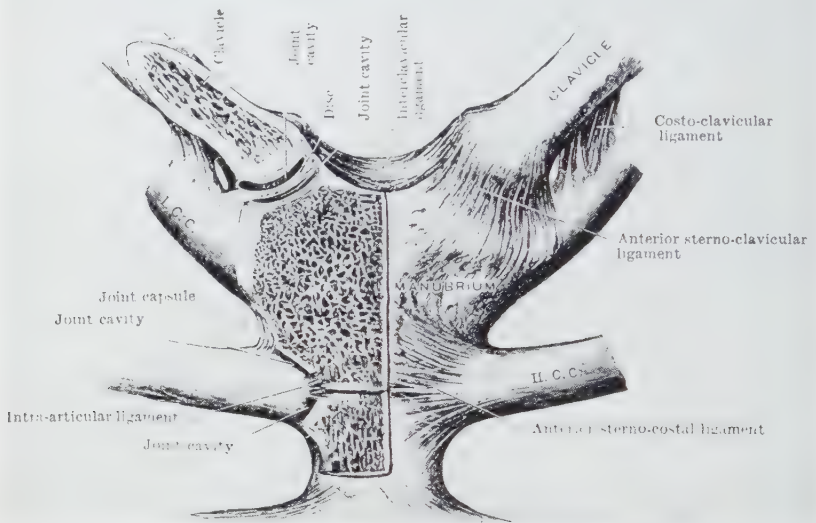


Fig. 1 Diagram of the upper end of the sternum showing the different types of joints. Note that in the case of the first rib (but not the second or others) bone is joined to bone by cartilage, without the intervention of a joint cavity. Apparently the same is true in most cases for the superior intersternal joint, although the diagram is not clear on this point. (After Cunningham's fig. 300).

changes resolve themselves." So far as I can discover, all textbooks of anatomy fail to mention epiphyses in descriptions of the ossification of the sternum. Probably this is due to the delicacy and prompt union of the epiphyseal plates in the areas of the sternal joints. Naturally, ununited plates would be lost in skeletal maceration and hence would not be seen. On the other hand, the possibility exists that these plates sometimes are reduced in size or not formed at all, and

this view is supported by such findings at the sternal end of the clavicle (Todd and d'Errico, '28).

DESCRIPTION OF THE SEQUENCE OF MODIFICATION

Although the foregoing anatomical details help explain the changes observable in the sternum, anyone attempting to assess age from this bone should first study a series of immature specimens in order to appreciate the range of variation in size, shape and details of joint arrangement. Training the eye to distinguish between random variation and progressive modification is essential to correct interpretation of age. In the description of the modification sequence that follows, a few typical specimens have been selected from the many examined to tell the story. Here, then, variability must be referred to as something to be taken into account, and not singled out for special treatment.

First, let us look at a few sterna from in front and arranged according to physiological growth stages (plate 1). Note that in only two of the 6 bones displayed is the corpus united into a single piece of bone. In the two that are thus united the epiphyses of the long bones are also united, and hence these individuals may be regarded as being past the age of 20 years. The other 4 bones, being from younger individuals, show various stages of fusion involving different numbers of elements (between 3 and 5). Also, it is clear that, although the elements of the corpus are erratic in uniting, the top element is generally the last to fuse. On this basis alone it is often possible to distinguish skeletons of the second and third decades.

Plate 1 also affords a front view of the superior intersternal joint. In the three examples shown in plate 1, note that the contact between the manubrium and corpus widens with age. On this basis one would expect a corresponding progressive modification of the joint surfaces. Indeed, it is a general rule for such joints, as Todd was always careful to point out, that before adulthood the surfaces and borders are rounded and soft-textured; but during the third decade angularity and hard-texture appear. Other than this reference to conformity of the

joint surfaces I will not have much to say about the changes in the superior intersternal joint, the reason being that most of these changes parallel others which deserve more attention.

We turn next to the conjoined articular areas for the clavicle and first rib at the superolateral angle of the manubrium. Plate 2 shows 9 manubria standing on edge so as to show the areas of particular interest and also arranged by physiological growth stages. Beginning at the left end of the upper row, note that in the first three the facets for the clavicle and first rib are poorly differentiated. Moreover, the articular surfaces are dimpled or billowed and have a matte-like finish or texture. As will be recognized by those familiar with the skeletons of adolescents, such an appearance is typical of a joint in the stage preceding epiphyseal union. So far as I can judge now this stage continues here until 17 or 18 years of age.

Before leaving these three specimens, I call attention to the lower edge of the articular area for the first rib. This edge is well defined in the second and third specimens but not in the first. The distinction here is not due to age, but represents instead a common variation. The first specimen is an example of a bone in which at this age all of the borders, except that in the midline superiorly (the jugular notch), have the appearance of developing into articular surfaces. In such a case the facet for the first rib ultimately would develop a lower edge, but otherwise the lateral border of the bone would always reflect the appearance seen here. An understanding of this condition makes the picture less confusing.

Now we turn to the next three bones in plate 2, that is, the last two on the top row and the first on the bottom row. These three specimens show different stages of epiphyseal union. In the first of the three, the epiphysis for the clavicular facet is in the process of uniting. There is no indication of an epiphysis for the adjacent rib facet. Indeed, the latter surface still has the appearance of being prepared to receive an epiphysis. By contrast the second specimen has incompletely attached epiphyseal plates on both surfaces, and on the surfaces of the conjoined intersternal and second chondrosternal joints as well.

The third specimen, on the other hand, has progressed still further. Here the articular surfaces are completely glazed over. Yet the appearance of the facet for the first rib in this third specimen would suggest that an epiphysis for this area never formed and that a glazing of mature bone had served as a substitute. The latter process is probably of common occurrence at this site. In any case, since at least two of the skeletons involved are in the stage where the proximal epiphysis of the humerus is uniting, I would judge that the stage of sternal maturation under consideration takes place around 19-20 years of age, although it may extend over a longer period.

Before leaving the second group of three bones, I call attention to the developing eminence at about the midpoint in the conjoined articular areas. As will be seen by looking ahead in plate 2, this eminence is to develop into a sharp transverse ridge which will form the boundary between the two well-defined facets. Thus in due course a ridge will provide the superior edge of the facet for the first rib and the lateral edge of the facet for the clavicle. However, at the time these articular areas receive their epiphyses, or glaze over, the eminence is still rounded and incomplete ventrally. Until the ventral interarticular notch is filled in and the eminence is transformed into a transverse ridge delimiting the facets, the manubrium cannot be said to have reached maturity. According to present indications the interarticular notch disappears, and the transverse ridge is formed, when the epiphyses of the innominate are about united; in other words, early in the first half of the third decade.

With these events in mind, we are ready to examine more closely the last three bones in plate 2. The first shows the signs of maturity just described. In this case the epiphysis at the sternal end of the clavicle is uniting, which would be before 25 years of age according to Todd and d'Errico ('28). The second differs from the first mainly in having formed a raised rim around the edges of the facets for the first and second ribs. Just when the rim appears is not certain, but probably it is between 23 and 30 years of age. Later, as the third speci-

men shows, this rim disappears into the bony spurs so characteristic of hypertrophic or degenerative arthritis. Between these events the surface of the facet for the first rib becomes more porous, owing perhaps to the fact that it is not an arthrodial joint like its neighbors. I am inclined to believe that this unique chondrosternal joint is among the first to show degenerative changes. In any case, arthritic lipping probably appears here early in the fourth decade.

We come now to plate 3 showing, with one exception in lateral view, both the manubrium and corpus from 4 individuals. The purpose of this plate is to show two things: (1) part of the sequence of modification in the lower chondrosternal joints, and (2) variation in thickness of the superior intersternal joint. The first specimen on the left is in the late stage of maturation already described where, in the manubrium, the ventral interarticular notch is just disappearing. Indeed, in this case the filling-in of the notch seems to be taking place along with the union of epiphyses in most of the chondrosternal facets. This probably represents one of the sequential variations that one would expect to encounter in a large series. At least this specimen makes it clear that all of the chondrosternal facets may have more or less complete epiphyseal plates present and uniting either just before the ventral interarticular notch fills in or along with the filling in thereof.

Reference was made in connection with the anatomy of the joints to the fact that the third costal facet may show signs of the recent fusion of the upper elements of the corpus. Although the first specimen in plate 3 scarcely demonstrates this fact, the second and third specimens show a division of the third facet by a transverse cleft. The resemblance in the latter specimens of the third costal facet and the second costal facet (as divided by the superior intersternal joint) should be apparent. Observe, however, that the cleft in the third facet is being bridged over both dorsally and ventrally. The bridges probably are equivalent to the rims of the other joints. Although the cleft may persist into middle age, the presence and thickness of the bridges give some idea of the relative age.

The fourth specimen shows the appearance of the lower costal facets around middle age and before they develop arthritic lipping.

Finally, I call attention to the increased ventrodorsal thickness of the superior intersternal joints in the second and fourth specimens. Actually, in the second specimen this joint is partly fused. As for the fourth specimen, the manubrium has been turned so as to expose the inferior joint surface and to show that this surface has begun to break down. The appearance suggests that here, too, is an intersternal joint on its way to fusion. Although thickening of the bone does not always accompany fusion of this joint, it seems to represent bone reaction connected with joint disturbance, and hence one of the conditions leading to fusion. Regardless of the causes of synostosis in this joint, age is not a factor in the process, as Trotter ('34) has pointed out.

SUMMARY

In view of the need for information about age changes in the human sternum, I have explored the subject in a series of skeletons representing the native peoples of North America. Although, under the circumstances, it is impossible as yet to assign definite ages to developmental events, and variability in rate of development cannot be evaluated, the association of these events with datable age changes in other bones should prove useful in assessing the age of skeletons. Thus the metamorphosis of the sternal joints in very tentative terms may be outlined as follows:

1. *Up to the time the proximal epiphysis of the humerus is uniting (up to 17-18? years).*

Component elements of the corpus sterni are still identifiable, although those in the inferior two-thirds may have fused. Joint surfaces here and in the manubrium are rounded, dimpled or billowed, and exhibit a matte-like surface texture.

2. *Coincident with, and somewhat following, the union of the proximal epiphysis of the humerus (about 19-20? years).*

Epiphyseal plates can be found in all stages of union on the clavicular facets. At the end of this period epiphyseal plates are beginning to unite on the rib facets, or failing the formation of plates, the articular surfaces are beginning to glaze over. Also, in most cases, the superior element of the corpus is fusing with the element next below.

3. *Coincident with the union of the epiphyses for the iliac crest and ischial ramus (about 20-23? years).*

The eminence marking the boundary between the articular areas of the clavicle and first rib gives way to a sharp transverse ridge. The last step in the formation of this ridge is the filling-in of a ventral interarticular notch. At this time the facets for the third ribs are usually divided by a transverse cleft, the last remaining sign of the recent fusion of the superior element of the corpus.

4. *Coincident with and immediately following union of the epiphysis at the sternal end of the clavicle (about 23-30? years).*

Raised rim is formed around the articular areas of the first and second ribs and those of the superior intersternal joint. By this time the superior intersternal joint has broadened so that the articular surfaces are rectangular. Facets for first ribs become slightly more porous. Clefts in facets for third ribs are being bridged across ventrally and dorsally.

5. *Just before or coincident with the appearance of arthritis in the vertebrae (about 35 years).*

Hypertrophic bone spurs appear around the margins of the facets for the first ribs, particularly ventrally and dorsally and more above than below. The other rib facets develop spurs much more slowly. Also, there may be progressive, disorderly break-down of the joint surfaces.

ADDENDUM

When this paper was submitted for publication in May, 1954, the opportunity to pursue the subject further seemed unlikely to come about for some time. Yet events took a sudden change by the latter part of the summer and I was able to go to Japan in September for

the purpose of examining the skeletal remains of American soldiers received in exchange from the Communists through Operation Glory. Accordingly, I have reviewed and corrected the present paper in the light of this experience. Eventually I hope to amplify and document the sequence of sternal modifications associated with age here merely outlined.

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PLATE 1

EXPLANATION OF FIGURES

Front view of a series of sterna selected to show certain developmental features discussed in the text. Left to right:

<i>U.S.N.M. no.</i>	<i>Racial group</i>	<i>Physiological age marker</i>
377923	Aleut	Beginning union of distal epiphysis of humerus
364785	Eskimo	Proximal ulnar epiphysis in advanced stage of union
345357	Eskimo	Beginning union of proximal epiphysis of humerus
366610	Koniag	Proximal epiphysis of humerus uniting
308643	Pueblo	Epiphysis at sternal end of clavicle uniting
314292	Pueblo	Long bone epiphyses united; very slight arthritis; probably beginning suture closure



PLATE 2

EXPLANATION OF FIGURES

Lateral view of a series of manubria selected to show certain developmental features discussed in the text. From left to right:

<i>U.S.N.M. no.</i>	<i>Racial group</i>	<i>Physiological age marker</i>
Top row:		
374625	Koniag	Permanent M ² erupted; distal epiphysis of humerus ununited
377923	Aleut	Beginning union of distal epiphysis of humerus
363656	Koniag	Epiphysis for medial epicondyle of humerus uniting
345357	Eskimo	Beginning union of proximal epiphysis of humerus
327128	Pueblo	(No associated bones)
Bottom row:		
366610	Koniag	Proximal epiphysis of humerus uniting
377706	Koniag	Epiphysis for sternal end of clavicle uniting
374626	Koniag	Long bone epiphyses united; no arthritis; some suture closure
372815	Koniag	Epiphyses united; moderate arthritis; advanced suture closure



PLATE 3

EXPLANATION OF FIGURES

Lateral view of 4 sterna (1 manubrium turned over to show the inferior articular surface) selected to show certain developmental features discussed in the text. Note the thickening of the bone at the superior intersternal joint in two of the cases. From left to right :

<i>U.S.N.M. no.</i>	<i>Racial group</i>	<i>Physiological age marker</i>
308642	Pueblo	Epiphysis at sternal end of clavicle uniting
377902	Aleut	Epiphysis at sternal end of clavicle united; no arthritis
378691	Aleut	Epiphyses united; beginning arthritis; advanced suture closure
225259	Sionx	Beginning arthritis; advanced suture closure





GENETIC EFFECT OF IRRADIATION.—There is another basic difference between irradiating *Drosophila* eggs and the ovaries of nonpregnant women, namely, in the reproductive cycles. The *Drosophila* reproduces itself in about 10 days, some 30 generations being produced within one year, although its life cycle is about 90 days. After irradiation, little time is left between generations for full recovery from its effects to take place. In contrast to secondary effects on progeny of the *Drosophila*, an interval of at least 20 years elapses between generations in populations of western countries. Twenty-seven years passed before a follow-up note could be made on the second “seed generation” in the case reported here. The grandchild appears to be normal by all pediatric standards.

This is the 5th such case recorded; Kaplan has encountered 4 others. The long span of time between generations obviously makes it difficult to give an absolute answer to the theoretical question of the ultimate harmful genetic effect of irradiation on the human race. But the long interval of time between births of a first and second generation would warrant the assumption that whatever harmful effects may have been produced by the x-ray irradiation to the ovaries of a grandmother would have been dissipated over the years. No acquired lethal effects on the genes have been observed in hundreds of babies born following this treatment for the relief of infertility and delayed menstruation. The additional record of 5 normal grandchildren fails to support the claim that low dose x-ray irradiation to the ovaries and pituitary produces harmful effects in human reproduction.—I. C. Rubin. Third generation follow-up in woman receiving pelvic irradiation. *J. Am. Med. Assn.*, vol. 150, no. 3, Sept. 20, 1952, pp. 207–209.

KURT BRÖSTE.—After a long, and as it turned out, hopeless illness, Kurt Bröste, M.D., died in Copenhagen on the 26th of April, 1954, at the age of 52. Since 1941 he had been director of the Laboratory of Physical Anthropology of the University of Copenhagen. Under his leadership a series of scientific articles were issued from this institution, articles mainly dealing with the anthropology of prehistoric peoples in Scandinavia as well as in the Eskimo areas. Unfortunately he did not live long enough to finish his lifework, a great book on “Prehistoric Man in Denmark” of which only the first volume has gone into print.

We who are left to continue his work will do our best to keep up to his brilliant example, always remembering with gratitude his keen brain, his never failing cheerful encouragement and genuine interest in his pupils.—J. Balslev Jorgensen, M.D.

A PRELIMINARY STUDY OF ESTIMATION OF WEIGHT OF THE SKELETON

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Human skeletons and selected bones have been weighed in the fresh, dry and ashed states; at various ages ranging from the 8th fetal month to 78 years; and, from both fresh and embalmed bodies.

Theile (1884), for example, studied the weight of the skeleton in a series of 11 young subjects up to 7 years. Several were newborn and of these one was a premature infant. He reported both fresh and dry weight of individual bones and demonstrated an increase in weight with increase in age. It may be assumed that the bones were from unembalmed bodies, that they had been allowed to air-dry over a long period, and that they were not degreased.

A series of 100 White male skeletons ranging in age from 19 to 78 years was weighed by Ingalls ('31). These are in the Todd Collection and therefore from embalmed cadavers. They had been macerated, cleaned and dried, but not degreased (N. L. Hoerr, personal communication, '54). They were selected for age, with 20 skeletons in each 10 year period, from 20 to 80 years. Stature was not considered. Ingalls presented the mean weight and the range but the values according to decades are relative to the mean value of the total number rather than absolute. Briefly, the means for the decades differ from the mean for the total series through a range of 4.1%. The decades in which the means fall below the total mean are the twenties, the forties and those after sixty; whereas, the skeletons in the thirties and in the fifties weigh 1.5% and 1.8%, respectively, more than the total mean. It is

of interest that Ingalls states. "There is no question but that bone gives very definite evidence of age, but that these changes also affect materially the weight of bone is another matter."

Studies of the chemical composition of the human body which include information concerning the percentage ash weight of certain bones and of the total skeletons have been made on two American White adult males. In 1945 Mitchell, Hamilton, Steggerda and Bean analyzed a White male, 35 years old with a total body weight of 70.55 kg. The body was not embalmed. Following dissection to separate the various organs and tissues, this skeleton weighed 14.84% of the total body weight and the ash weight was 56.67% of the weight of the dry, fat-free skeleton. Three individual bones (left tibia, ulna and 9th rib) were ashed separately. Their ash weights (in per cent of the dry, fat-free weights) showed differences, not only among themselves, but also, when compared with the percentage ash weight of the total skeleton.

In 1953, Forbes, Cooper and Mitchell studied another White male, 46 years of age, 53.80 kg in weight, and not embalmed. After dissection the skeleton was found to weigh 17.58% of the total weight. The percentage ash weight of this skeleton was 56.89% of its weight in the dry, fat-free state. Again, three individual bones were ashed separately, and again differences in the weights were found. However, the percentage ash weights of comparable bones and of the total skeletons in these two studies were very similar. The authors point out that the data support the thesis that analysis of a single bone is not likely to give a true estimate of the composition of the entire skeleton.

Matiegka ('21) evolved a formula for determining the weight of the skeleton in the living based on stature and "the maximum transversal dimension of the lower end (a.) of the humerus, (b.) of the forearm, (c.) of the thigh bone, and (d.) of the leg; in other words the transverse diameter of the humeral and femoral condyles and of the wrists and ankles . . . the squared average of the 4 dimensions — o (ossa)² — multiplied by stature in centimeters — L (Length), gives a

value representing the weight of the skeleton ($O = \text{skeleton}$).'' He remarked that ''the osseous parts of the extremities give us a good idea of the skeleton as a whole,'' and, that ''the weight of the skeleton except in old age, is but little liable to changes.'' He suggested that his formula should be tested on a series of cadavers.

The present report is based on a study of skeletons in the Terry Collection. The weight of the skeleton is related to age, stature, and certain other measurements. It is an attempt to determine the reliability of estimation of the weight of the skeleton from data which can be gathered from the living.

MATERIAL AND METHODS

Twenty-four White male skeletons in the Terry Collection were selected for study. The range in age is from 18 to 87 years. They were selected for completeness of parts and for age range, with three or four in each decade.

Stature had been measured when the cadaver was received in the laboratory (Trotter and Gleser, '52). The period during which they were received extended from 1925 to 1940. Each cadaver was embalmed with either 10% formalin, or with a solution combining two parts of glycerine, two parts of 95% alcohol and one part of phenol crystals. Before dissection the bodies were stored for varying periods in 3% carbolic acid. Following removal of soft parts, the skeletons were prepared for the Collection by the Terry method. This involved immersion of the bones in hot water (96° - $98^{\circ}\text{C}.$) for 72 hours or less after which the remaining soft parts were removed with either a hard bristle brush or a soft wire rotating brush. They were then laid on a tilted drain board and allowed to dry at room temperature. When thoroughly dry, the ''greasy'' skeletons were placed in a Leipzig degreaser and exposed to fumes from benzol for a period of approximately 17 hours. After removal from the degreaser they were allowed to stand for a day. The bones were then ''sized'' by dipping in a very thin solution of glue which

contained 3% carbolic acid. Finally, they were dipped again in 10% formalin which sealed the glue.

The bones were weighed individually except for the following: skull, movable vertebrae, sacrum and coccyx (if fused to sacrum, otherwise excluded), ribs, hand and foot. These were weighed as named. No attempt was made to include the hyoid and ear bones, or to estimate the weight of missing teeth. Finally, the skeleton was weighed *in toto* and the figure compared with the sum of the weights of the individual parts. The two weights do not show perfect agreement and there is no consistency in one or the other always being the larger figure. The average difference between the two is small, 22.05 gm, or .49% of the mean skeleton weight.

The maximum length of each femur was measured on the osteometric board and the average of each pair recorded. The maximum bi-epicondylar diameter of the humerus, the bi-styloid (or bidistal epiphyseal) diameter of the articulated radius and ulna, the bi-epicondylar diameter of the femur, and the bimalleolar diameter of the articulated tibia and fibula were taken on the osteometric board. The weight of each skeleton was estimated according to Matiegka's formula by substituting the appropriate diameters of the skeleton for the diameters he recommended in the living. He wrote of 4 diameters. In this study 4 pairs of diameters have been measured and are referred to as 8 transverse diameters.

Each pair of femurs was suitably posed with a metric rule at the side and a photograph was taken. The negative was projected from an enlarger until the length of the images, both of the bones and the rule, equalled their actual lengths. The outline of the image was traced in pencil and the enclosed area was measured by the planimeter. The sum of the areas of each pair is recorded in square centimeters.

The middle half of each pair of femurs was x-rayed with the tube 6 feet from the film (10" \times 12"). The bones were placed with the mid-points of their lengths in line with the mid-diameter of the film. Also, over this mid-diameter, between the bones and at a level midway from the film to the

most posterior part of the bones (excluding the linea aspera), was placed a brass strip which had been notched along one edge at millimeter intervals. Postero-anterior views were made. Reproduction on the film was actual size. From these films, the areas of the shadows of compact bone in the middle half of the femur were determined with the planimeter. First, the entire area of the middle half of the shaft was found, and then the area within the borders of the compact bone (designated as medullary cavity but, including the area of cancellous bone as well). The latter figure was subtracted from the former and the result was considered to be the area of the compact bone. The sum of the areas of compact bone (in actual size x ray) of the middle half of the length of each pair of femurs was recorded in square centimeters.

All statistical analyses have been carried out by Barbara Bartels Hixon, to whom grateful acknowledgment is made.

RESULTS

Table 1 presents the Terry Collection numbers of the skeletons listed according to increasing age, and data pertaining to each skeleton.

These data comprise 10 independent variables denoted by X_i , each with its appropriate subscript and of the dependent variable, Y , the weight of the skeleton. The independent variables are:

- X_1 Cadaver stature (cm).
- X_2 Age (years).
- X_3 Average weight of femurs (gm).
- X_4 Average maximum length of femurs (cm).
- X_5 Average bi-epicondylar diameter of femurs (cm).
- X_6 Average bi-epicondylar diameter of humeri (cm).
- X_7 Estimate of skeleton weight according to Matiegka's formula (gm).
- X_8 Sum of 8 transverse diameters (humerus, articulated radius and ulna, femur, articulated tibia and fibula, of each side) (cm).

TABLE 1
Data pertaining to each skeleton listed according to age

NO.	AGE	STAT.	FEMUR		DIAMETER		EST. WT. MATTIEGKA	8 T. D.	FEMUR AREA	COMPACT BONE	SKELETON WEIGHT
			Weight	Length	Fem.	Hum.					
	<i>years</i>	<i>cm</i>	<i>gm</i>	<i>cm</i>	<i>cm</i>	<i>cm</i>	<i>gm</i>	<i>cm</i>	<i>cm²</i>	<i>cm²</i>	<i>gm</i>
335	18	158	220	41.8	7.1	5.4	5133	45.6	267.4	33.4	3075
645	20	188	442	49.0	8.6	6.6	8821	54.8	409.0	56.2	5146
591	28	171	375	46.1	7.7	6.6	7363	52.5	344.1	60.6	4330
303R	30	187	500	49.6	9.0	6.6	8934	55.3	428.9	67.5	5006
301R	36	181	410	48.6	8.0	6.5	7794	52.5	394.3	65.0	4545
111R	38	159	275	38.8	7.1	5.7	5031	45.0	277.4	57.6	3252
131R	39	170	354	45.6	8.2	6.3	7432	52.9	360.2	58.7	4165
184R	42	181	448	46.6	8.6	6.8	9027	56.5	404.8	67.7	5256
763	46	179	585	46.2	8.2	5.7	7332	51.2	379.2	72.0	6128
315	48	173	435	46.8	8.6	6.6	8448	55.9	406.0	65.3	4746
305	57	169	430	45.4	9.0	6.8	8340	56.2	400.0	63.7	4892
316	57	177	384	49.2	8.4	6.4	7917	53.5	387.6	54.6	4076
73R	59	165	308	40.8	8.0	6.2	6706	51.0	340.4	51.4	3710
136R	59	170	462	44.6	8.0	6.4	7127	51.8	371.3	57.0	5376
314	65	168	385	45.1	8.4	6.8	7654	54.0	360.0	62.0	4526
5	67	180	540	48.6	8.3	6.6	8385	54.6	432.2	75.2	5770
784	68	169	322	46.0	8.4	6.4	7306	52.6	399.4	51.3	3512
313	69	170	388	45.4	8.4	6.4	7320	52.5	368.1	56.5	3813
307	72	169	420	48.2	8.7	6.6	7757	54.2	387.8	63.2	4965
758	73	170	405	46.6	8.5	6.6	7861	54.4	393.6	66.7	4578
806	78	168	473	45.9	8.8	7.0	8440	56.7	409.4	57.3	4950
804	81	161	300	43.4	8.2	6.0	6492	50.8	350.8	58.2	3473
317	84	172	358	46.6	8.4	6.6	7837	54.0	389.0	55.3	4030
805	87	168	320	45.0	8.0	6.4	6668	50.4	374.2	50.4	3712
Mean	55.0	171.8	397.5	45.88	8.28	6.42	7546.9	52.87	376.46	59.42	4459.9
S.D.	20.3	7.8	84.4	2.62	.48	.38	1026.7	2.96	40.18	8.50	800.8

X_9 Sum of areas of projection (from an anterior view) of femurs (cm^2).

X_{10} Sum of areas of compact bone (as shown by x ray, postero-anterior view) in middle half of femurs (cm^2).

The correlation coefficient, r , of each independent variable, X_i , with skeleton weight, Y (the dependent variable), and the probability, P^1 , associated with each is presented in table 2. In addition, the correlation coefficient of certain independent variables with each other are given.

The correlation coefficient of cadaver stature with age is not significant but shows a negative trend which is in accord with the results of an earlier study demonstrating loss of stature with age (Trotter and Gleser, '51). Cadaver stature is correlated significantly with weight of the femurs, with length of the femurs, with the sum of 8 transverse diameters, with area of compact bone in the middle half of the femurs, and with weight of the total skeleton. It may be noted that the correlation coefficient between stature and length of the femur ($r = .8215$) for this series of 24 White male skeletons is almost the same ($r = .861$) as was found for a series of 255 White male skeletons from the same Collection (Trotter and Gleser, '52).

Age is not correlated significantly with femur weight, with femur length, or with skeleton weight. The negative trend, however, in the first and last of these three pairs is in accord with the belief that bones become lighter in weight with ageing.

Femur weight is significantly correlated with femur length and with weight of the total skeleton. The high correlation coefficient ($r = .9591$) between femur weight and weight of the skeleton is demonstrated by the analysis of variance to be significant at the .001 level. The standard error of estimated skeleton weight is 231.71 gm. Thus, approximately one-third of all estimates of skeleton weight derived from average

¹ The probability is the chance of obtaining a correlation coefficient as large or larger than the present one from a random sample of an uncorrelated, bivariate population.

TABLE 2
The correlation coefficients of each independent variable with weight of the skeleton and of certain independent variables with each other, and P of each

	X_2	X_3	X_4	X_6	X_8	X_{10}	Y
Stature	X_1 — .3094 not sig.	.7325 < .001	.8215 < .001		.6055 < .01	.5740 < .01	.6909 < .001
Age	X_2	— .0129 not sig.	.0124 not sig.				— .0826 not sig.
Femur weight	X_3		.6369 < .001				.9591 < .001
Femur length	X_4						.5833 < .01
D. of femur	X_5			.7599 < .01			.5344 < .01
D. of humerus	X_6						.4319 < .05
Estimated wt.	X_7						.7007 < .01
8 T. D.	X_8					.5731 < .01	.6208 < .01
Femur area	X_9						.7159 < .001
Compact bone	X_{10}						.7634 < .001

weight of femurs would differ from the actual skeleton weight by 232 or more grams.

The average maximum length of the femurs is correlated significantly with total skeleton weight.

In testing Matiegka's formula on this series of skeletons his recommendation could not be followed strictly. The diameters were measured on the bones rather than on the cadaver. The transverse diameters of the femur and humerus probably are altered less from the comparable diameters in the cadaver than are the diameters of the articulated bones of the leg and forearm. For this reason the average diameters of the femurs and humeri were examined in relation to each other, and in relation to total skeleton weight. The coefficient of correlation between the two diameters, between the diameter of the femur and skeleton weight, and between the diameter of the humerus and skeleton weight are significant; the last, however, only at the .05 level.

The weight of each skeleton was estimated according to the formula of Matiegka. The correlation coefficient between these estimates and the actual weights is .7007, significant at the .01 level; it is practically the same as was found between stature and skeleton weight ($r = .6909$). Were it a higher correlation coefficient it would be worth while to revise Matiegka's formula by finding the appropriate constant for a regression equation. He proposed a constant of "from 1 to 1.2 (still to be tested on corpses)."

The sum of the 8 transverse diameters is significantly correlated with the sum of the areas of compact bone in the middle half of the femurs and with total skeleton weight. Both are significant at the .01 level.

The sum of the areas of the projection of the femurs is significantly correlated with skeleton weight. The correlation coefficient is .7159, only slightly higher than the correlation coefficient of stature with skeleton weight ($r = .6909$). Both are significant at the .001 level.

The sum of the areas of compact bone has a significant correlation coefficient with femur weight ($r = .7988$), and a

higher correlation coefficient with skeleton weight ($r = .7634$) than has any of the other independent variables except femur weight. Unfortunately, femur weight cannot be determined on the living subject.

The multiple correlation coefficients, R , of certain combinations of these independent variables with skeleton weight have been determined, looking toward the establishment of

TABLE 3

Multiple correlation coefficients, R , of certain independent variables with the dependent variable; their probabilities, P ; and their standard errors of estimate

INDEPENDENT VARIABLES	DEPENDENT VARIABLE	R	P	S.E.
				<i>gm</i>
Stature and age	Skeleton weight	.7045	< .01	594.8
Stature, age and femur weight	Skeleton weight	.9631	< .001	231.2
Transverse diameter of femur and of humerus	Skeleton weight	.5359	< .05	707.6
Sum of 8 transverse diameters and stature	Skeleton weight	.7362	< .01	567.1
Sum of areas of compact bone and stature	Skeleton weight	.8234	< .001	475.5
Sum of areas of compact bone, stature and 8 T. D.	Skeleton weight	.8302	< .001	478.7

a multiple regression equation which could give an estimation of skeleton weight with a minimum estimate of error.

It may be seen from the table that estimation of skeleton weight based on these 6 different combinations of variables will vary most from the actual weight when the transverse diameter of femur and of humerus are utilized, and almost as much when the sum of the 8 transverse diameters and stature comprise the determining factors. Stature and age are equally poor variables from which to estimate the weight of the skeleton. The best multiple correlation coefficient involves the combination of stature, age, and femur weight.

However, the standard error of estimate of this combination (231.2 gm) is no more precise than when femur weight alone is used (231.7 gm). The sum of the areas of compact bone in the middle half of the femurs (x ray) and stature give a multiple correlation coefficient with skeleton weight of approximately the same value ($R = .8234$) as in the case when an additional independent variable is considered, the 8 transverse diameters ($R = .8302$). The standard error of estimate is approximately the same for both, and smaller than for any other combination of variables except the one which includes femur weight, a variable which cannot be obtained in the living.

The hip bones and skull each contribute large amounts, relatively, to the total skeleton weight. The pelvis was articulated and its greatest breadth measured; also, the greatest antero-posterior and transverse diameters of the skull were measured. There is not sufficient indication of correlation, either between the breadth of the pelvis and the weight of the hip bones, or between the diameters of the skull and its weight, to warrant further statistical exploration.

Thus, it is suggested from this preliminary study that the weight of the skeleton can be estimated in the living with approximately one-third of the estimates differing from the actual weights by 476 gm or more. The independent variables, stature and the sum of the areas of compact bone in the middle half of the femurs (x ray), required to establish a regression equation with this estimate of error, may both be determined on the living.

DISCUSSION

The chief difficulty in determining a formula for estimation of weight of the skeleton is obtaining a suitable series of skeletons for study. The series should represent an unbiased sample of the population. The skeletons should be prepared not only in a uniform manner but also in a manner which produces uniformity with respect to shrinking, to residual water, and to fat. Another difficulty in the preparation of skeletons for weighing in the fresh state is the separation

of tendons, ligaments and cartilages from the bones. Most of the problems involved could be obviated by determining the ash weight, but a series of skeletons for ashing is difficult to obtain.

Skeletons in the Terry Collection are derived from dissecting room bodies. Two different solutions were used for embalming. The bones are not dry and fat-free in the sense that chemists use those terms. But the preparation of these skeletons has provided considerable uniformity within the series.

The selection of 24 White male skeletons for this study was made for a wide range in age. The selection provides also a wide range in cadaver stature (158–188 cm) and in total skeleton weight (3075 gm–6128 gm). In Ingalls's series of 100 White male skeletons from the Todd Collection, the range of total skeleton weight was somewhat greater (2984 gm–6976 gm), with the greater difference at the higher end of the range. The mean weight of Ingalls's series (4957 gm) is also greater than of the present series (4460 gm). These differences may be accounted for perhaps by the small number in the present series and also by the fact that the Todd Collection skeletons were not degreased.

The lack of significant correlation between age and total skeleton weight supports the observation of Ingalls that changes in bone with age do not affect materially the weight of bone. Such changes as closure of skull sutures, lipping of the vertebral bodies, etc., do not occur simultaneously and probably have an age order of appearance in the different parts of the skeleton.

The long limb bones are certainly the last parts of the skeleton to show age changes. Of these long bones the femur is the longest and heaviest. Its weight has a highly significant correlation with weight of the total skeleton. The general characteristics of the femur were studied by Ingalls ('24, '32) who concluded that the diaphysis is distinctly more variable than the epiphyses and that the transverse measurements of the shaft are more variable than those taken in the sagittal plane. For these reasons the outline area of the femurs was

taken from an anterior view and the area of compact bone was determined on the middle half of the femur from a postero-anterior x ray.

Transverse diameters and circumferences of various parts of the body have been utilized as criteria for estimates of total body weight as well as for classification of human physiques. No doubt, most measurements of parts of the body will show considerable correlation with each other and with measurements of the total body. But the need in the present problem is to find those measurements which provide the best coefficients of correlation with total skeleton weight and which can be measured on the living. The transverse diameters proposed by Matiegka ('21) are measurements which are significantly correlated with skeleton weight, but stature is better correlated with skeleton weight. Area of the femur (projection of anterior view) shows some improvement over stature in its correlation with skeleton weight, but the area of compact bone of the middle half of the femur (x ray) has a still higher correlation coefficient with total skeleton weight.

Thus, it is indicated that the amount of compact bone is a more significant factor than the size of the bone in assessing the weight of the skeleton.

SUMMARY AND CONCLUSION

Twenty-four White male skeletons from the Terry Collection were weighed. The stature and age of the cadavers from which they came were known. Additional measurements were made on the bones. The data were analyzed statistically, in an attempt to relate selected variables, from which a regression equation for estimation of skeleton weight with a minimum standard error of estimate might be determined for application to the living.

The mean weight of the skeletons is 4459.9 gm and the standard deviation 800.8 gm. Stature is significantly correlated with skeleton weight but age and skeleton weight are not significantly correlated. The correlation coefficient be-

tween the average weight of the femurs and the weight of the skeleton is .9591. The standard error of estimate of skeleton weight, estimated from the average weight of the femurs is 231.71 gm.

Matiegka's formula for estimating skeleton weight from stature and maximum transverse diameters of the distal ends of arm, forearm, thigh and leg was tested by substituting cadaver stature and the transverse diameters of the appropriate bones for the measurements of the living. The correlation coefficient between the resultant estimated skeleton weights and the actual skeleton weights is .7007 — practically the same as was found between cadaver stature and skeleton weight.

Measurements of the femur tested for correlation with skeleton weight are length, area of a projection from an anterior view, and area of compact bone (as shown by x ray) in the middle half of its length. The last of these three variables provides the highest coefficient of correlation with skeleton weight. The combination of stature, the area of compact bone in the middle half of the femur, and skeleton weight, has a multiple correlation coefficient of .8234 significant at the .001 level. The standard error of estimate of skeleton weight determined from these two variables is 475.5 gm.

Thus, of the independent variables which have been tested, and may be obtained from the living, the weight of the skeleton may be estimated with the least standard error of estimate from stature and the sum of the areas of compact bone in the middle half of the femurs (as shown in an x ray, postero-anterior view). The estimated weight will vary from the true weight in one-third of the cases by as much as, or more than, 475.5 gm which is approximately 11% of the mean weight of this sample of White male skeletons in the Terry Collection.

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NEW LIST OF LANDMARKS.—It is necessary to prescribe a system of exact landmarks which will permit searching analyses of human morphological characters, as much for the skeleton as for the soft parts. Such a system of “morphologic” points does not yet exist. However, it would be illogical to try to develop this without taking into account the foundations already current in anthropometry. It is with this aim that we have composed the present Repertoire. It is intended to give a list of some of the classical landmarks of anthropology, some of which are of primary importance and others, on the contrary, only secondary. In attempting to make this Repertoire as complete as possible, we believe that it remains for a future Congress of specialists to eliminate superfluous points and to harmonize others. We have restricted ourselves to adding certain new craniometric landmarks the utility or worthlessness of which will appear on practice; and above all, to bringing a little order into the chaotic state of the abbreviations (without accomplishing this altogether).

The etymological justification of certain terms figuring in this Repertoire is often weak. The latter were criticized already at the time of the direct disciples of Broca (for example, by Fauvelle). More recently, J. Koumaris proposed a whole nomenclature in which he sought to avoid the mixture of Greek and Latin roots. This concern with etymological purity, although legitimate, seems to us secondary, and the less offensive neologisms have been accepted since they deal with clear and universally admissible ideas. We hope that the completeness of this Repertoire, which is its distinctive trait, will contribute to the uniformity and precision of the methods used in the somatic study of man. Without this uniformity and precision, the most laudable efforts will remain sterile and fragmentary.—R. Kherumian. *Répertoire des points craniométriques et anthropométriques*. *Revue de Morpho-Physiologie Humaine*, no. 2, 1949, 22 pp.

SEASONAL CHANGES IN SKIN COLOR

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ONE FIGURE

In a recent paper (Lasker, '54), I have used a photoelectric reflection meter to analyze skin color differences in closely related populations. The present study is an application of the same method to the investigation of seasonal changes. By measuring the same group of persons periodically, I hoped to demonstrate the extent of darkening of the skin during the summer months and the rate of loss of "tan" during the winter and to determine which of several areas of skin is least affected. One purpose of this paper is to elucidate further which areas and what color of filter would be most usable in field studies of racial differences in skin pigmentation.

Twenty white American medical school students and staff members (17 male and 3 female) were examined on — or approximately on — the first day of each month, with the exception of August and September, from March 1952 through March 1953. Reflectance values were taken from three areas of skin: the middle of the forehead above glabella, the flat area lateral to the hypothenar eminence between the fourth and fifth metacarpals of the palm of the right hand, and the groove corresponding to the medial intermuscular septum in the middle of the right upper arm.

After correcting the readings to correspond to percent of reflectance from magnesium oxide and further correcting the peak wave lengths of the filters to allow for skewdness of the color temperature of the light source and the response curve

of the photocell, the averages recorded in figure 1 and table 1 result.¹

Individual month-to-month changes vary from the group averages because different individuals expose themselves to sunlight on different days. (Edwards and Duntley, '39, have shown that 11 hours after one hour of exposure, an individual may show changes in reflectance greater than any demonstrated by our averaged figures.) Individual variability also encompasses the experimental error of the technique. In the present study only one reading was recorded with each filter for each area of skin on each individual per month.

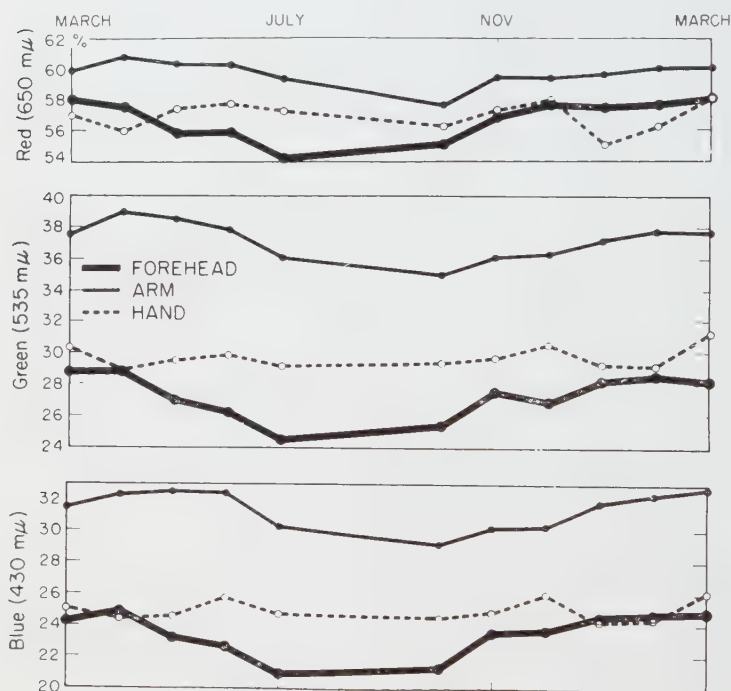


Fig. 1 Reflectance from skin (percentage of that from magnesium oxide). Averages of measurements on 20 American white subjects.

¹ A table of the individual measurements has been deposited as Document number 4300 with the ADI Auxiliary Publication Service, Photoduplication Service, Library of Congress, Washington 25, D. C. A photoprint or microfilm copy may be secured from them on advance payment of \$1.25.

When the mean month-by-month changes, which are plotted in figure 1, are divided by the standard errors of the differences between successive months, 29 of the 90 changes are statistically significant (two or more times their standard error). The two chief seasonal changes in arm and forehead reflectance are seen. The forehead becomes darker on the average in respect to all wave lengths during April and June; the arm during June and subsequent months, but the change in readings with shorter wave length filters is apparently

TABLE 1

*Mean reflectance from skin at various peak wave lengths
Twenty white subjects*

DATE BEGINNING OF	FOREHEAD			HAND			ARM		
	Blue 430 m μ	Green 535 m μ	Red 650 m μ	Blue 430 m μ	Green 535 m μ	Red 650 m μ	Blue 430 m μ	Green 535 m μ	Red 650 m μ
March	24.3	28.8	58.0	25.0	30.3	57.0	31.4	37.6	59.9
April	24.9	28.8	57.6	24.4	28.9	56.0	32.3	39.0	60.7
May	23.2	26.9	55.7	24.6	29.5	57.3	32.4	38.5	60.2
June	22.6	26.3	55.8	25.7	29.8	57.6	32.4	37.8	60.2
July	20.9	24.4	54.2	24.6	29.1	57.2	30.3	36.1	59.3
October	21.3	25.4	55.1	24.5	29.3	56.2	29.1	35.0	57.6
November	23.5	27.6	56.8	24.7	29.6	57.2	30.2	36.1	59.4
December	23.6	26.9	57.6	26.0	30.6	57.7	30.3	36.3	59.3
January	24.5	28.2	57.4	24.3	29.3	55.0	31.7	37.1	59.6
February	24.7	28.5	57.5	24.4	29.2	56.2	32.3	37.8	59.9
March	24.8	28.1	58.1	26.1	31.2	58.1	32.7	37.7	59.9

somewhat retarded — which corresponds to the fact that the skin reddens before it darkens. Both forehead and arm become more reflective (i.e. lighter) during October for all wave lengths and, with the shorter wave length filters, also during December and March.

The hand measurements become darker during December and lighter during February, but no ready explanation for this is available. Small amounts of dirt on the hand have been observed to cause a depression of 20% in reflectance readings of the hand and, even after washing, ingrained dirt can cause even greater depression of reflectance values. Variability be-

tween individuals in month-to-month changes in reflectance is much greater for the hand than for the forehead or arm. A few direct tests for reliability with the same individual measured repeatedly on the same or successive days also indicate that the variability in hand reflectance is appreciably greater than that at either of the other two points of measurement. Thus, despite the lack of summer depression in light reflection from the palm of the hand, this measurement does not lend itself to studies of skin color as well as do measurements of other areas.

Reflectance values with different filters are highly inter-correlated. Product-moment correlations have been calculated using the data of all individuals for all months. The correlations incorporate both interindividual and intermonth variances. For the inner arm, for instance, the product-moment correlations and their standard deviations are: red with green, $+ .864 \pm .017$; red with blue, $+ .861 \pm .018$; and green with blue, $+ .901 \pm .013$. Melanin absorption of light at all tested wave lengths probably explains these high correlations.²

Because of the correlation of readings of skin reflectance over the visible spectrum, any one narrow band will give a satisfactory index of skin pigmentation. A red filter is probably best for this because: (1) It is most reproducible in tests of reliability (so far only a few unsystematic tests are available to support this assertion); (2) Reflectance from skin increases towards the red, reaching a maximum in the infra-

²If there were only one figure, or an average, for each individual the correlations would be higher. Furthermore, in a group of individuals with more diverse skin colors the correlations are higher still. For instance, from a series of individuals tested with the same technique by 4 graduate students of the University of Chicago, Patricia Anderson, John Donahue, Robert Peherson and Walter Sangree (personal communication, 1953) I have selected 57 individuals to represent the widest racial differences (14 U. S. whites, 2 British whites, 2 Puerto Rican whites, 1 Iraqi, 1 Arab, 1 Iranian, 6 East Indians — 5 from India, one from Trinidad, — 7 Japanese, 3 Chinese, 2 Thais, 2 Filipinos, 1 Korean, 11 U. S. Negroes, 2 West Indian Negroes, 1 Gold Coast Negro, and 1 Liberian) and find the following correlations: red and green filters, $r = + .949 \pm .013$; red and blue, $r = + .941 \pm .015$; and green and blue, $r = + .942 \pm .015$.

red; and (3) Marked effects of recent exposure to the sun, such as those recorded by Edwards and Duntley ('39), would be most pronounced with shorter wave lengths (such as in the green at 535 m μ where there is a marked absorption of light by oxyhemoglobin) while in the red at 650 m μ the effects of exposure to sunlight are relatively smaller and apparently retarded.

To summarize, objective records of reflectance of visible light from skin reveal seasonal variations in a group of young American white adults. This factor must be taken into account in studies of racial differences. Technically, studies of the inner arm and forehead are more reliable than those of the palm of the hand. Likewise a red filter with long peak wave length is in some ways superior, in studies of skin pigment, to green or blue filters. As reflectance at different wave lengths is highly correlated, red filter measurements of one or two areas of skin provide an objective index of darkness of the skin, but seasonal differences caused by exposure to the sun are an appreciable factor at all wave lengths.

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THE SCALP IN HEALTH AND DISEASE. By Howard T. Behrman. C. V. Mosby Company, St. Louis. 566 pp. 1952.—In “The Scalp in Health and Disease” Dr. Behrman has written a thoroughly up-to-date text. Admittedly expensive (\$12.75), it contains 512 drawings and photographs and a large number of references, including over 500 on the embryology, anatomy, and physiology of the hair, the skin glands, and alopecia.

Though many sections are fascinating in themselves, and Doctor Behrman’s stand on detergent rinses, lotions, and hair dressings is commendably frank, the chapters on male pattern balding and the normal anatomy and physiology of the hair should prove of major interest to anthropologists. In discussing male pattern balding the work of J. B. Hamilton is followed in detail, though some space is allotted to Young’s fat-loss theory of balding and the multiple-factor Szasz-Robinson hypothesis is reviewed. The latter, it may be recalled, invokes genes, hormones, fat, scalp muscles *and* muscular tensions arising out of the cultural context.

Chapter 1 (100 pages), devoted to the anatomy and physiology of hair, includes a comparison of the pilous systems of rodents and men, and summarizes some of the work of Kneberg, Steggerda, Trotter, Danforth and others. Pilometric studies are discussed, and the Copley pilometer is described. The molecular structure of hair and the alpha-beta keratin shift are also considered, as are the recent studies on the red hair pigments by Rothman and Flesch. In discussing the role of hormonal secretions on hair growth, Speert’s work on topical applications has not been employed to advantage, and much basic information on nutritional achromotrichia has been displaced in favor of clinical studies. However, this book is directed primarily at the clinician, who in turn may care less for those sections that will interest anthropologists most.

SELECTION AND POLYMORPHISM IN THE A-B-O BLOOD GROUPS

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TWO FIGURES

After many years of discussion and debate about the racial distribution of the A-B-O blood groups, several questions still have not been answered to the satisfaction of all students. Three of the questions are purely historical: (1) At the point where the line of human descent diverged irrevocably from all others, did it carry one, two, or all three of the A-B-O allelomorphs? (2) If not all of the genes were part of the basic human inheritance, which are the more recent mutations? (3) Have these more recent mutations occurred as unique events, or has each recurred from time to time in various populations? The 4th question is functional, though closely related to the historical questions: (4) Is there any selective value attached to the A-B-O blood group genes or to the genotypes formed by them?

To these questions the present paper proposes to add a 5th, which must be considered relevant to the others: (5) Why has only a small part of the possible range of A-B-O blood group frequencies been realized by now existing races? At first glance this may seem an unreasonable question, like asking why there are upper and lower limits to human body size; but in respect to characteristics which have been frequently assumed to lack any selective value, the question becomes an interesting one. Figure 1a, adapted from a compilation by Wiener ('43) shows graphically the distribution of 215 representative human populations all checked for consistency by the equations of Bernstein. Our adaptation shows

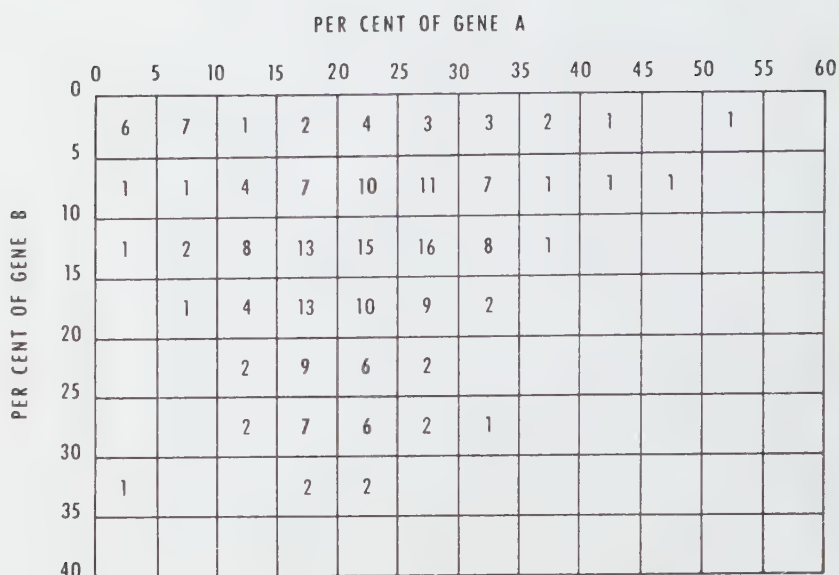


Fig. 1a Quantitative distribution of 215 representative human populations in respect to frequencies of the A-B-O blood group genes.

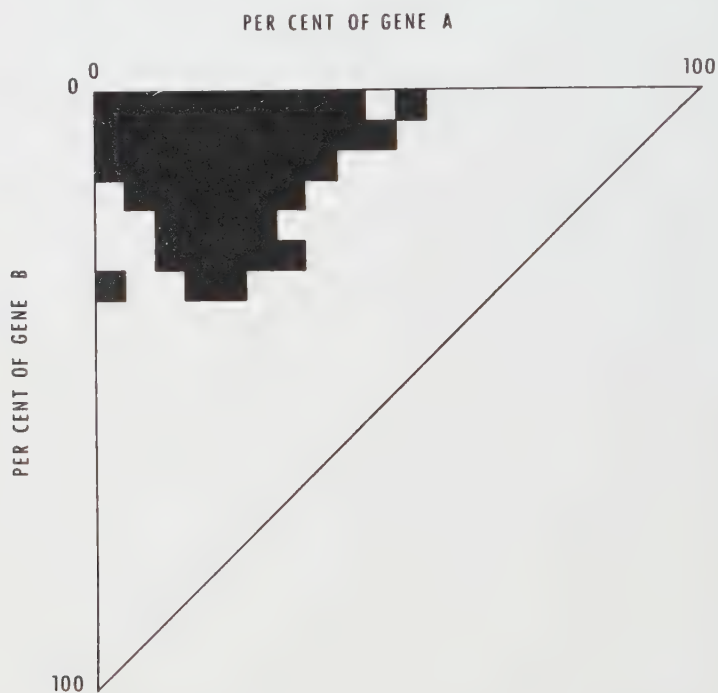


Fig. 1b Limits of the world range in A-B-O blood group frequencies, in relation to the complete possible range.

only the number of series reported in each group range, so that it represents various races somewhat in proportion to the number of times they have been studied, although duplicating and repetitious values have been largely eliminated by the original compiler. Since the principal value of the figure is to demonstrate the outside limits of variation so far recorded, a further check was made on the accompanying tabular series of 351 populations, and a few at or near the limits of variation were added.¹ No further data were inserted, since the sampling seemed sufficiently broad in its coverage to define the range of variation for our present purposes. In order to present the distribution in proper perspective, which is usually not done for space-saving reasons, figure 1b has been prepared to show the outlines of the "inhabited portion" of the A-B-O gene frequency range, in proportion to the total possible range for the genes. It will be seen that about four-fifths of the possible range is vacant or nearly so.

Certain generalizations about the distribution may be made. The O gene is rarely reduced below 50%, and then only by a small amount. In the absence or near-absence of the A gene, the B gene usually remains low. In the absence or near-absence of the B gene, the percentages of the genes A and O are rather widely distributed, from zero to 50% A. Where the frequency of the B gene is high, on the other hand, the range in respect to O and A is more restricted, centering around 20% gene A. There seems no way in which the peculiarities of this distribution can be explained in terms of random independent fluctuations of the A, B, and O genes; there appear to be some correlative factors acting between them. This must be explained either by particular historical circumstance or by the assumption that selective factors operate to make certain areas of the chart "uninhabitable." The nature of the limiting factors which have resulted in

¹ We have concurred with Wiener in eliminating one Tibetan series, with gross inconsistency between A, B, and AB frequencies, which would have showed a frequency of gene O lower than any group here included.

the world distribution we now have must be such as to counteract genetic drift, which will always tend to diversify populations and break down limits such as appear in figure 1.

The following discussion will therefore include both negative and positive arguments. Historical reconstructions based on the assumption that the A-B-O genes lack selective value, which include a variety of hypotheses regarding the origin and relative antiquity of the three genes, must be examined to see whether they can satisfactorily account for the present ranges of frequency of the three genes. To some extent the geographical distribution of the genes, especially B, so often discussed before, must be reviewed again. Then it will be necessary to determine whether a hypothesis involving selective factors can explain these data more satisfactorily. This will require the preparation of a mathematical model of a selective system, into which must be incorporated any direct evidence now at hand for selective effects involving the A-B-O genes. First, however we must consider genetic drift, mutation, and selection, particularly as they may apply to the blood group genes and as they have been invoked in the past to explain the polymorphism of the human species in respect to this gene system.

GENETIC DRIFT

The effect of genetic drift producing random variations between fragments of races, where population numbers are small, is certainly substantial in respect to the blood groups, often in contrast to the apparent stability of a combination of other traits. This has been interpreted, according to the prejudice of the observer, either as indicating that other traits are standardized by some form of selection (Boyd, '50) or that because of their multiple rather than simple genetic determination they are less susceptible to the random fluctuations of single genes (Birdsell, '50). Genetic drift has been delicately defined in mathematical terms by Wright and others; (Wright, '49, '51; Dobzhansky, '41, '50) but since it has sometimes been rather poorly described in anthropologi-

cal literature it is well to recapitulate. The genes present in any generation of a given group represent a statistical sampling of the genes present in the germ cells of the previous generation. Within certain slight limitations (due to the fact that there is a maximum practicable family size in the species) these genes represent a random sample of the statistical universe defined by the gene frequencies of the previous generation. The variance of such a sample may be calculated by the formula \sqrt{Npq} . In a tribe with an average complement of 1,000 individuals (2,000 genes of any given set of allelomorphs) a 25% frequency of any gene in one generation will become $25 \pm .65\%$ in the second generation. This variance is cumulative, so that as time goes on the distribution of possible future values derived from the starting point of 25% frequency acquires a progressively higher probable error. Hence in any population which breaks up into isolated subgroups, the gene frequencies of the subgroups will become progressively more dispersed as time goes on; and if the total population is small and the subgroups few, any inference as to the original gene frequencies will be uncertain in proportion to the smallness of the population and the length of time elapsed. This means unfortunately that the affinities of some most interesting groups, Lapps, Bushmen, Congo Pygmies, etc., are perhaps beyond the reach of valid deduction from blood group evidence, though much attention has been given to them. Later increase in size will not reverse any peculiarities acquired while a group is small.

The effects of genetic drift are strongly evident in respect to the A-B-O gene frequencies within populations otherwise distinct and relatively homogeneous. Figures for a few selected groups, in which isolation or low population numbers are favorable to drift, speak for themselves. Frequencies of the A gene only are given, since B will be discussed later with emphasis on factors other than drift. The North American Indians are of course outstanding for bracketing the entire world range of A gene frequency from 0-54%; and though they undoubtedly began with some diversity of strains,

there is no indication that this is directly correlated with the present differences. Other groups which are reasonably homogeneous in morphological features but show a large range in A-gene frequencies are Pre-Dravidians, with an A-gene range of 34% between various subgroups; Eskimos, with a range of 32%, Polynesians, with 28%, Australians with 24%, and Ainu with 17%. Of course the comment may be made that various subgroups of the populations cited above have been subject to influence from different admixtures. But where the range between subgroups of a principal group is half or more of the total world range (as in the first 4 cases cited) it is not possible to find supposed mixing groups extreme enough in A-B-O frequencies to produce this diversity. In marked contrast also are the rather mild gradients of A-B-O frequency found within continental European nationalities or between adjacent ones. In these cases we know of admixtures and infiltrations from different directions as historical facts; yet, in the presence of high population densities in this area, the diversity of gene frequency is very low compared to the examples cited above. The evidence for the vigor of genetic drift under more primitive conditions is so convincing as to be disturbing. If it has acted so strongly even after the formation of certain races and subraces as we now know them, why has it not produced, during the whole period of the differentiation of the species, often under conditions of isolation and smallness of numbers more marked than have existed subsequently, a range of variation much greater than we now see? We can hardly assume that A-B-O gene frequencies remained stable during the period when other fundamental racial differences were developing, only to scatter centrifugally by genetic drift after the other racial differences had been clearly developed; this would virtually imply higher population densities at the earlier period than at the later. But if the present scatter within racial groups such as cited above is projected over the whole period of racial differentiation, with nothing to control it, it would seem that nearly every possible percentage distribution of the A-B-O genes

would have been realized by some now existing group. If we attempt to explain the control of genetic drift in the blood-groups by assuming continual back-crossing of human strains, we cannot account for the maintenance of the other racial differences. We might express this phenomenon in the form of a rather unorthodox equation:

$$\frac{28\% \text{ difference in frequency of A gene}}{\text{maximum difference between any two Australian tribes in other features}} = \frac{X\% \text{ difference in frequency of A gene}}{\text{difference between Australians and any other race in other features}}$$

X, which would represent the potential world range for the A gene, could clearly go up to 100% (or more) without violating the terms of the equation. It appears then that a disproportion exists between the development of local and total diversity in regard to blood groups, with a total world range of blood group frequencies somewhat restricted as compared to what might be expected on the basis of local conditions.

ORIGINS OF THE A-B-O GENES

The question of the present average range of human populations in respect to the A-B-O blood group has always been closely involved with hypotheses regarding the time of origin of the three allelomorphs. An early explanation assumed that only one of the genes, O, was present in the original human stock, and that the other two "arose" and "spread" at different times from a hypothetical diffusion center for the species, thereby producing the general pattern of distribution now seen. Unfortunately the words "arose" and "spread," which roll so easily off the tongue or pen, are in the nature of genetical time-bombs. Many things have been calculated about the future of a new-born mutation. Its situation at the beginning is precarious in respect even to mere survival, and even if by favorable chance it manages to arrive at a level of frequency which prevents its actual loss in some generation, its chances of becoming abundant are very slight, unless it possesses some selective advantage. It may persist as a constant minority in a large group, or achieve a fairly

high percentage value in a small group, but its absolute numbers are likely to remain small indefinitely. The parallel frequently cited of newer or more progressive traits "spreading" from centers, in the evolution of other genera or orders is an entirely proper one as regards the behavior of a mutation of positive selective value; it cannot properly be applied to a mutation which we choose to consider entirely neutral in value. One explanation which recognized this difficulty attributed the eventual frequencies attained by genes A and B to the fact that the entire species, at the time the mutations occurred, consisted of so few individuals that chance alone could bring the new genes up to appreciable percentages. The geographical distribution was accounted for by supposing that A "arose" very shortly before the first invasion of the New World, so that the invading groups carried a small amount of it, and subsequently "spread," i.e. increased its percentage value, in the population remaining in the Old World. If this "spread" in the Old World occurred purely by genetic drift, we must assume that the basic immigration into the New World was accomplished while the nucleus of the human species in the Old World still consisted of a few thousand individuals. In regard to the development of B, which would appear by all evidence to have come later, the situation is even more paradoxical. Now a fairly well populated world is assumed, with the corners of the Old World and the New filled with the genes A and O in various proportions, while somewhere in Asia a small group in some way isolated, developed a high percentage of the B gene purely by genetic drift from a chance mutation. Then subsequently this B-bearing group multiplied explosively, expanded outward as the result of a supposed "superior culture" and eventually established the B gene in substantial amounts throughout Asia, the Pacific Islands, Africa and Eastern Europe, till it constituted about 15% of the A-B-O genes of the human species. It appears to the present author that this plot is too much contrived, adjusting population size, degree of isolation, and even cultural advantage, to suit the case.

The basic difficulty is that the word "spread" as applied to a gene, whether the user so intends or not, implies selective advantage of some kind.

Numerous variations on this general scheme have been proposed. One attempts to explain the building up of the A and B genes, without selective advantage, by assuming that the mutations occurred repeatedly; this of course does not explain the existence of geographical difference in distribution unless a particular mutation occurred repeatedly in one population without occurring in another. Since this virtually assumes a pre-existing genetic difference predisposing to the occurrence of a particular mutation, it pushes the problem back one step without explaining it. A similar theory speaks of "precursors" of genes from which the final mutations occurred to produce the genes as we now know them. However, for historical purposes, and to explain the geographical distribution of the A-B-O genes at the present time, it little matters whether at a given moment in the past a gene existed as a predisposition to mutate, as a "precursor," or as the real thing; the problem of explaining the geographical distribution of the genes remains the same.

The notion of repeated mutations has sometimes been applied in a more logical way, by assuming that the mutations occurred more or less at random in various populations, sometimes becoming extinguished, sometimes hanging on, and occasionally multiplying with isolation and good luck. This would serve to explain some of the erratic behavior of the gene frequencies, such as the occasional B in the New World; undoubtedly the sporadic recurrence of the various mutations should be taken into consideration as a possibility regardless of how we propose to explain the broader aspects of A-B-O gene distribution. However, if various mutations involving these genes have been occurring occasionally throughout human history, it is probable that they occurred early enough to make all three forms, A, B, and O, for practical purposes coeval with the human species. The latter supposition is the

basis for the other principal school of thought in regard to A-B-O gene distribution.

If it is assumed that all three allelomorphs were present at the "birth" of the human species, the present geographical distributions are accounted for by relative degrees of gene loss in the early stages of dispersion when communities were small. The probable starting point was set by Boyd (Schiff and Boyd, '42) at 25% A gene, 15% B gene and 60% O gene — a present average for the species. Clearly, in the process of dispersion and genetic drift B is the most likely to be lost by some groups, A the next. It is assumed that a number of groups lost B, and that the B-less groups were in very large part the ones which first populated the New World, Australia and western Europe. (It should be noted that these must have been not only small groups, but few groups, else some groups enriched in B by genetic drift would have gone along to counteract the B-less groups.) The gene B then remained only in the larger (presumably) breeding group of continental Asia where it was protected from extinction by the size of the group in which it occurred. Then in some way B, within this larger group, increased to frequencies of 20–30% in one or more subgroups, which expanded outward and spread B by mixture over a very extensive area. Since B is supposed to have increased markedly in the larger central population, which would be less subject to genetic drift, it might be preferable to start out with a primeval frequency of B nearer to its maximum in present groups than near its average. In regard to A this theory supposes that, being in the beginning commoner than B, it reached all areas in reasonable amounts, there to give rise by genetic drift to a variety of combinations with O.

With regard to explaining the non-random features of the total chart of frequencies, the two main approaches outlined above (addition of genes by mutation, deletion of genes by drift) present very much the same aspect. In either case the result is best explained by assuming that at some time in the past a particular group, with a frequency of the A gene

about 20%, developed maximal values of B, and produced the peculiar triangular distribution of figures 1a and 1b by mixing with a variety of B-less groups ranging from zero to 50% in gene A. This would account for the tendency of the high B groups to converge in respect to their percentage of the A gene. Whether the high-B group was the group in which the B gene originated or the one in which it solely remained after loss in other areas, does not affect the subsequent course of events. In considering the probable effects of such mixture we must take into account two aspects of the process; the production of a basic frequency of the B gene intermediate between the mixing groups, in proper proportion to the amount of mixture; then variations in the resulting hybrids due to genetic drift in separate population fragments.

The present highest levels of the B gene (ca. 30%) include representatives of groups which are otherwise quite diverse; Indians (including Pre-Dravidians), Gypsies, Chinese, Indonesians, classical Mongoloids of Manchuria and Siberia, and Ainu. If we assume that these groups arose by the mixture of various groups which lacked the B gene altogether, with a hypothetical "B-race," it is evident that even if the "B-race" was 100% saturated with the B gene, the amount of common admixture in these cases would have to be about 30%. It seems most doubtful that a 100% saturation of the B-gene could have been attained by genetic drift alone in a population large enough subsequently to modify the blood group picture of the world on a continental scale. If the "B-race" was less saturated with the gene B, the amount of mixture must have been still more. Of course, other representatives of the same groups mentioned above are much lower in respect to B-gene frequency; Pre-Dravidians, for instance range down to 8% B gene, Indonesians to 11%, classical Mongoloid to 12%, Ainu to 16%. If these intra-group differences were due to different amounts of admixture with the "B-race," and if the amount of mixture involved was in some cases 30% or more, the "B-race" should have produced a visible differentiation within these groups in other

physical features; almost enough, one would suspect, to prevent them from having been considered "groups" in the first place. (Ashman, who has explored the "B-race" hypothesis very carefully, has suggested that it had a 70% frequency of the B-gene. This would involve 50% admixture with it in some of the groups mentioned above.) The necessity of massive amounts of mixture may be obviated if we assume that the groups involved had retained a respectable amount of a primeval B. But in reducing the assumed amount of admixture with the "B-race" we reduce the standardizing effect of this mixture on the frequency of the A gene. By another approach the necessity of assuming that different Ainu groups, for instance, received markedly different amounts of the B-race without showing diversity in other traits could be explained by supposing that genetic drift has subsequently scattered various Ainu subdivisions which once were alike in B gene frequency. But in this case the A-gene frequencies should also have become diverse as the result of drift, and most markedly in those groups whose circumstances had favored extreme drift in the direction of high B gene frequencies. Yet in fact all these highest-B groups tend to cluster about 20% A gene, regardless of the greater diversity in A frequencies of their low-B relatives. This was the phenomenon that the assumption of a single source of B, acting by mixture, was supposed to explain.

Perhaps only one non-controversial thing may be said about gene B; it appears that a very large proportion of the B genes now in existence have radiated from a single area of origin somewhere in Eastern Asia. This has been attributed to the phenomenal expansion and migration of some particular and originally small population group. The fact that high B-gene levels cross-cut racial differences as distinct as between Ainu and classical Mongoloid, however, strongly suggests another hypothesis which most students have handled gingerly if at all—namely that the B gene has a positive selective value, and tends to increase disproportionately in any group which once becomes infected with it. Birdsell ('50)

has offered this suggestion in explanation of the frequency of the B gene in Australia, which seems to him to be out of proportion to the amount of admixture which introduced it, as, he adds succinctly, "in so many other areas of the world." The Ainu might represent a later stage of such a process, originating from the "infection" of an O-A population by a relatively small B-bearing group. A selective advantage of the B gene, even if slight, would eliminate numerous dilemmas of historical reconstruction which we have touched on above. Selection, however, brings new problems. If the B gene is constantly and universally favored by selection, then all human populations containing it would be unstable as regards their A-B-O gene frequencies, and on the move in the direction of higher B. We do not like to assume that we have happened to observe the B gene in a short transitional period between its absence and its universality, and that the present maximum B gene frequency of 36% is only this millenium's maximum. This sort of reasoning was no doubt responsible in part for the now traditional view that the blood group genes are non-selective. However, in more recent years a balanced type of selection has been recognized, in which heterozygotes and homozygotes of the same gene have different selective values, so that the gene has selective advantage at some percentage levels and not at others. This phenomenon termed "balanced polymorphism," which has been carefully studied by Ford and others, can actively maintain the coexistence of different allelomorphs, and would be capable of controlling the extreme vagaries of genetic drift. It does not now seem possible, as it did before the extent of genetic drift was appreciated, to suppose that the coexistence of the genes A-B-O, within a limited range of frequencies, has been maintained passively for millennia by virtue of an absolute neutrality as regards selective value.

SELECTION AND ITS CONSEQUENCES

Recently the question of selection in the A-B-O blood groups has been raised in a more concrete form. Waterhouse and

Hogben, following a line of investigation first suggested by Hirszfeld in 1925, have shown that selection against the phenotype OA, of a very severe sort, takes place when the OA embryo develops in an OO mother. The data which they have assembled show that only 75% as many A (OA) children are born to O women with A husbands as to A women with O husbands, although the frequency of the two reciprocal types of marriage, and the relative per cents of OA and AA genotypes included under the phenotype A, would be the same for any population or combination of populations. The effect is shown in deficiency of recorded fertile matings, deficiency of total number of children produced, and deficiency of A children produced. They estimate therefore that 25% of the OA embryos exposed to this risk are eliminated, apparently by an incompatibility similar to that produced by the Rh genes.² A selective effect of any such magnitude immediately raises a puzzling problem by rendering the A-B-O gene frequencies unstable in any population containing both A and O genes, unless in absolutely equal numbers. Selection against a heterozygote eliminates at each stroke one specimen of each gene, and will finally eliminate whichever of the two genes was in the beginning the less abundant. In the present case the B gene would be affected also, since in any internecine

²Currently Bennett and Brandt ('54) have contested this interpretation by breaking the question of significance of differences down into three parts: difference in numbers of the two types of matings encountered in a group of families which had proved fertile; difference in numbers of children per family appearing in the two types of matings; and difference in ratio of A to O children in the two types of family. They have showed that these portions of the phenomenon taken separately do not show statistical significance. However, no account is taken of the probability that all three of the events should have occurred in the same series and all in the same direction, namely that of reducing the number of A offspring to O mothers. The separate probabilities (the last calculated by the present author) are: for aberrance in representation of families, .12; for aberrance in respect to total fertility, .41, and for aberrance in respect to ratio of A and O offspring born to O mothers, .10. The product of these probabilities, which defines the likelihood of all three deviations having appeared concurrently is only .0049. It does not therefore appear that the newer analysis has abolished the phenomenon under consideration. It certainly must be assumed for the present as at least 200 times more probable than not that there is a shortage of A children to O mothers.

elimination of the genes A and O, B, if present in the population, would passively profit. Any one selective influence, therefore, throws the whole A-B-O system into a state of flux which demands some counter-selection to account for the maintenance of the three genes in the percentages in which we commonly find them. The most likely form of counter-selection in the present case would be a straight selective advantage in viability of the OA zygote (provided he survived the hazards of incompatibility). This however cannot be an exact antidote at all gene frequency levels. Straight selective advantage of OA would increase the number of OAs in direct proportion to the number expected to be produced in a given generation; elimination by incompatibility decreases the number of OAs in proportion to the number of them produced by OO mothers. Thus in each generation we add to the OAs a quantity OA multiplied by one constant and subtract a quantity O^2A multiplied by another constant. Obviously we cannot obtain by this means an equilibrium at all percentage levels of A and O genes. There will be instead a stable range or ranges of A-O gene frequency, at or near an equilibrium, and an unstable range or ranges where the advantages and disadvantages of the OA genotype do not satisfactorily cancel out. In order to conform to the pattern of world distribution it will be necessary to assume that the stable range covers the area in which existing groups have been recorded, i.e. from zero to 50% A gene, and that the unstable range is in the "uninhabited" area from 50 to 100% A. Eventually the B genotypes must also be related to the others in such a way as to explain the maintenance of the B gene at the levels at which it has been found to occur. If it is possible to hypothesize selective factors which would make the "empty areas" of figure 1b genetically unstable, we will have constructed a tentative hypothesis for explaining how the polymorphism of the A-B-O genes comes to be maintained within the range in which we find it.

The procedure followed was to concentrate first on the relations of A and O to one another in the absence of B, for

two reasons; first, because the existence of the incompatibility phenomenon definitely demands consideration of selective factors in respect to these two genes; second, because the known approximate magnitude of the incompatibility effect gives a concrete point of departure for determining other factors quantitatively. The second step was then to examine the possibilities of selective factors involving the gene B; a more speculative matter, not necessitated by known incompatibility, but strongly suggested by the apparent manner of diffusion of the B gene and the lack of randomness between B frequencies and A and O frequencies.

A HYPOTHESIS BASED ON SELECTION

In constructing a mathematical model to account for the limitations on existing A-B-O gene formulae, the basic assumption will be made that the present world range of distribution is in equilibrium and that no effects due to the comparative recency of occurrence of any one gene are evident. Even if B, for instance, is actually a "newer" gene, we will assume that it has had sufficient time to produce all the various percentage combinations with A and O that it is likely to form. We are assuming, then, that the distribution is essentially a permanent one and that its outlines will remain the same though in a sufficiently great length of time individual groups within it may shift. A corollary is that no deduction can be drawn from the mathematical model as to the greater age of any gene.

The mathematical model must satisfy several requirements. It must be such that the action of selective factors on any group located outside the present world range is such as to change that group's gene frequencies in the direction of a more normal ratio. The marginal groups will probably be (and, in fact, generally are) small and isolated groups in which genetic drift is such as to defy selection to some extent in an erratic fashion. The magnitude of the selective factors must be such that the "inward" trend is approximately the same at all points along the borders of the distribution. It

was not considered sufficient to have a general inward trend towards a central point suitably located; the selective factors should also account for the fact that the range of the A gene is less where B is high than where it is low. No attempt has been made to establish the absolute magnitude of selective pressure necessary to block genetic drift for practical purposes and form a "border" for the world distribution. This is of course a relative matter, since in smaller populations with greater genetic drift a group may extend further from the center against selective pressure than if it were more populous; one might picture a distribution of blood group gene frequencies of the human species in Paleolithic times having a far wider and more diffuse range than at the present time. Effort was therefore concentrated on obtaining correct *relative* values of selective pressure at various points, and demonstrating that the shape, not merely the general location, of the distribution could be accounted for by some sort of genotype selection.

Procedure

The first step in deriving a mathematical model for selection effects was to set down the frequencies of the 6 genotypes of the A-B-O system for each of the 50 combinations made possible by varying the gene frequencies in 10% steps. The value of OA in each square was then adjusted downward to represent the surviving OAs in a succeeding generation after the elimination of 25% of OA zygotes in OO mothers. This reduction is of course most marked in the presence of high frequencies of the O gene. Then each square was ready for the determination of the direction and magnitude of selection pressure which would affect it if the various genotypes had somewhat different survival values. Since the survival values of the various genotypes would have meaning only in relation to one another, it was decided to assign a neutral value to the abundant genotype OO, leaving only 5 variables. The survival values of the other genotypes were designated in plus or minus per cents; minus 5% meaning of a particular

type that 5% less would survive to reproduce than from an equal number of OOs (or that their fertility was 5% less). On this basis a set of hypothetical survival values for the various genotypes could be tested. A number of squares at key points in the distribution were selected, and their basic genotype distribution altered to correspond to the distribution which would appear in the second generation, each genotype being added to or subtracted from according to its assigned survival value. The genotype distribution was then broken down into the genes involved and the total of surviving genes in the second generation was calculated. (The total of surviving genes almost never comes to 100%, due to the up and down adjustments made, so that a true per cent has to be calculated each time. Attempts were made to set up equations for these changes, but they proved so ponderous and susceptible to calculation error that the more objective method was adhered to. It should be noted that anyone who attempts to estimate selection effects casually, without a final percentage adjustment, may be greatly misled.) The results of these calculations were recorded as "vectors" for each square; the vectors being the expected amounts of change in gene frequency per generation resulting from selective effects.

Certain generalizations about the effects of genotypic selection had to be considered before any scheme could be intelligently set up. As previously mentioned, selection in favor of a heterozygote will, where only two genes are involved, draw population frequencies towards the point at which each gene is 50%: selection against the heterozygote will draw population frequencies towards the two ends of the scale; i.e., result in elimination of one gene or the other from any population group. Where three genes are present, the third may become passively involved; loss of OA genotypes, for instance, will cause a relative increase of the B gene and vice versa. A high survival value of a homozygote will increase the one gene directly involved and produce a relative decrease of the other two; a low survival value for a homozygote will act to the advantage of both the other genes,

the gain being greatest for the one which is already the more abundant. In all cases the survival differential of any genotype, whether plus or minus, will have its greatest effect where the genotype is common; in marginal cases, in fact, when a genotype constitutes only 1 or 2% of the population, it can make only very slow progress even with a good plus survival value. Different selective values of the 6 genotypes therefore give rise to a complicated pattern of vectors, involving 6 foci; the three homozygous peaks where one gene is 100%, the three heterozygous peaks where two genes are each 50%. Since the effect of selection induced by any differential survival is most marked near the focus of its genotype, there is only a general resemblance between the effect of loss of OAs and the effect of gain in BBs, for instance; the first process acting most strongly where the B gene is rare, the second where it is abundant. This allows great flexibility in adapting a mathematical model to any given pattern.

First approximations were based on general deductions from the distribution shown in figures 1a and 1b. Since the distribution has a single center it seems likely that heterozygotes are in general more favored than homozygotes. If the latter had the higher survival value the distribution would tend to break up, with populations piling up in one or more corners of the range, producing A, B, or O "races." Biological success of the homozygote leads to "pure types;" this is not what we see in human blood group distribution. By the location of the center of the distribution we may assume that the homozygote OO is more favored by selection than AA or BB. The lack of groups having any appreciable amount of the gene B where O and B only are involved suggests that B does not have as much advantage as A in competition with O. A very general scheme was therefore set up with survival values as follows: OO, zero; OA, OB, and AB, plus; and AA and BB, minus. It was believed that OB should have a less positive value than the other heterozygotes, or BB a more strongly minus value than AA, to account for the generally lower frequency of gene B than of gene A. OA clearly must

have an outstanding positive value to counteract the fetal loss due to incompatibility. AB was at first set quite high as it was considered to represent the principal selective advantage of the B gene: this later proved untenable.

Equilibrium of O and A genes

In an arrangement of this kind there will normally be 4 points of equilibrium (exclusive of the cases where only one gene is present at all). Three of these represent cases where only two of the three genes are present; the 4th and most complexly determined will be the equilibrium where all three genes are present. The addition of the factor of incompatibility introduces another variable, however, which follows laws somewhat different, and gives rise to the possibility of still another equilibrium point on the O-A axis. The incompatibility loss, as previously mentioned, is not a fixed fraction of the number of OAs in any population, since the number of OAs subject to the risk depends on the ratio of OO to other genotypes among the mothers. If we are considering the O-A axis only, we find that the incompatibility effect ranges from a loss of 12.5% of all OAs where gene O equals 99%, to a negligible loss where gene O equals 1%. The compensation introduced by straight selection will be a fixed fraction of the number of OAs present at any point (in calculation this was considered a fixed fraction of the number of OAs left after incompatibility loss, not of the number present before such loss). Therefore, if the effect of straight selection is plus, and between 12.5 and 0%, it will overcompensate at some frequencies of the gene A and undercompensate at others. Where it overcompensates, the vectors will be directed towards 50% A gene, since the heterozygote will be at an advantage, and where it undercompensates the vectors will be directed away from the 50% point.

This produces a very interesting series of possibilities. Overcompensation at all levels (selective advantage more than 12.5%) would tend to shift all groups towards 50%

A gene. Undercompensation at all levels (selective advantage zero or less) would tend to shift groups centrifugally towards 100% A gene or 100% O gene. If the selective advantage just balances incompatibility where the A gene is 50%, the area between 100% and 50% A gene will be overcompensated, with vectors consequently directed towards 50% A gene, and the area between 50% and zero A gene will be undercompensated, with vectors directed down towards zero value of the A gene. In this case the A gene will progressively be eliminated, with a slight reprieve just at 50% A gene, a precarious equilibrium.

TABLE 1

Vectors produced by incompatibility loss of OA (25%) combined with selective advantage (10%) of surviving OAs where O and A are the only genes present in the population

	% OF A GENE IN THE POPULATION								
	10	20	30	40	50	60	70	80	90
Vector (change per generation in frequency of A gene in %)	— .16	— .10	+ .01	+ .07	0	— .22	— .47	— .79	— .63

The most complex result will ensue if the point at which selective advantage balances incompatibility loss lies between 10 and 40%, or between 60 and 90% A gene. This will produce a reversal in direction of vectors at the point of exact compensation (transition between over and undercompensation); moreover, it produces a reduction of vector values and consequently an alleviation of selection pressure near the point where the direction of vectors changes. This phenomenon can hardly be described without an example. In table 1 are given vectors based on incompatibility loss combined with selective advantage so that the two factors balance at approximately 30% A gene. (It is assumed that the B gene is not present.)

It is interesting to note the slowness of the vectors, all in fractions of per cents, despite the magnitude of the interacting factors. This vector system produces a range from zero to 50% A gene where selective pressure is relatively small, and

would allow considerable genetic drift of populations. It will be noted that there are three points of equilibrium; one at zero A gene, with a vector slope leading towards it; one at 50% A gene, with vector slopes leading towards it from both directions; and one at 30% A gene, with slopes leading away from it in both directions. It will be seen that the latter point, though an equilibrium, is a precarious one from which a group might fall away in one direction or another; however the vectors involved are so small that genetic drift might from time to time push groups over its hump to the other side. The final tendency would probably be to produce a somewhat bimodal distribution with concentrations at zero and 50% A gene, but always a certain number of groups in between.

Table 1 presents a picture consistent in general outline with the maintenance of the world distribution as regards populations in which the B gene is nearly or entirely absent. The alternative vector schemes described above which would tend to produce standardization at a 50% level of both genes, or breaking down of populations into a predominantly A division and a predominantly O division, are quite impossible — unless we accept the *ad hoc* hypothesis that one or the other gene is “new” and that a state of equilibrium has not been reached. The vectors of table 1 however could provide stabilization on a permanent basis; since the weak vectors between zero and 50% A gene would allow a scattering of groups throughout this range, and the much stronger vectors above 50% A gene would keep that area unoccupied. There are imperfections in this picture, however; there is not really an optimum point or accumulation of populations at 50% A gene; this is rather an extreme. The real center of the distribution along the O-A axis is more nearly at 30% A gene; the small number of groups near 50% seems to indicate that some countering of selective pressure is necessary to reach that point. Yet it is not easy to shift the upper end of our bimodal distribution down. If there is any degree of undercompensation at 50% A gene, tending to push A values down, this effect will be

present all the way down to 100% O gene, and the selective plateau of weak vectors which served to explain the wide spread of population gene frequencies from zero to 50% A has vanished.

This dilemma can be avoided if a negative value for AA is hypothecated. This possibility has already been suggested as a deduction from the average levels of the A and O genes in the species. A negative selective value for AA will reduce the A gene differentially with the greatest effect where the AA genotype is commonest. It was found possible by increasing the positive value of OA above that previously set, and introducing a negative value for AA, to produce a minus-A

TABLE 2

Vectors produced by incompatibility loss of OA (25%) combined with selective advantage (15%) of surviving OAs and selective disadvantage (6%) of AAs, where O and A are the only genes present in the population

	% OF A GENE IN THE POPULATION				
	10	20	30	40	50
Vector (change per generation in frequency of A gene in %)	+.10	+.14	+.03	— .26	— .74

vector at 50% A gene and at the same time retain the flatness and lack of strong vectors at 10–30% A gene. With the selective value of OA increased to plus 15% (which by itself would result in a piling up of all populations by strong vectors at 50% A gene) and a selective value of AA set at minus 6%, the vectors of table 2 are produced. This was considered a reasonable vector system to explain the present range of gene frequencies in populations having the A and O genes only. In view of the approximateness of the figure of 25% for incompatibility loss, which is involved in all vectors, it would be supererogatory to attempt to refine the mathematical model further.

Equilibrium of the B gene

In regard now to the B genotypes, it might be asked whether it is necessary that they also should have a selective value.

In a sense this question is meaningless; if OO, OA and AA have different values the B genotypes cannot be the same as all three; they must be placed somewhere on the scale, and there is certainly no necessity for them to be at that arbitrary zero point which was defined as equal to the survival rate of the OO genotype. The question then resolves itself into two parts: are the B genotypes identical with one another in selective value? and where are they located on the scale formed by OO, OA, and AA? We can assume that the B gene, in some combinations at least, must be better favored than OO, or else it could not establish itself at all except where the genotype AA is abundant; a picture not corresponding to the world distribution. It seems impossible to make BB equal to or superior to the heterozygous B genotypes, since then the gene B, if established at all in the heterozygous form, would rapidly progress towards a 100% frequency. But apparently the frequency of the B gene, like that of the A gene, is self-limited. So we have little choice but to assign plus values to OB and AB, and a minus value to BB. On this basis quantitative variations were tested until a pattern of vectors for both A and B genes, consonant with the limits of the world distribution, was obtained.

At first the attempt was made to attribute most of the positive selection of the B gene to a high survival value of AB, and to keep OB "down" in survival value, in order to account for the rarity of good development of the B gene in populations where the A gene is rare. This proved to have the effect, however, of encouraging B to the greatest extent where A was at a high rather than at a moderate level. It was finally decided that the principal effort would be devoted to obtaining a suitable vector pattern in the range in which all three genes were represented, and let the separate interactions of the O and B genes come out as they would. Successive approximations were made by a process of enlightened trial and error, finally resulting in the system of which the vectors are shown in table 3 and figure 2. This appeared to be about as satisfactory as could be obtained without defining

survival values in fractions of per cents. One comment should be made; if the survival factors of all the genotypes, exclusive of the basic plus value of 10% for OA which counteracts incompatibility effects, were to be changed within moderate limits *in proportion to one another*, the vector patterns would remain approximately the same except that the magnitude

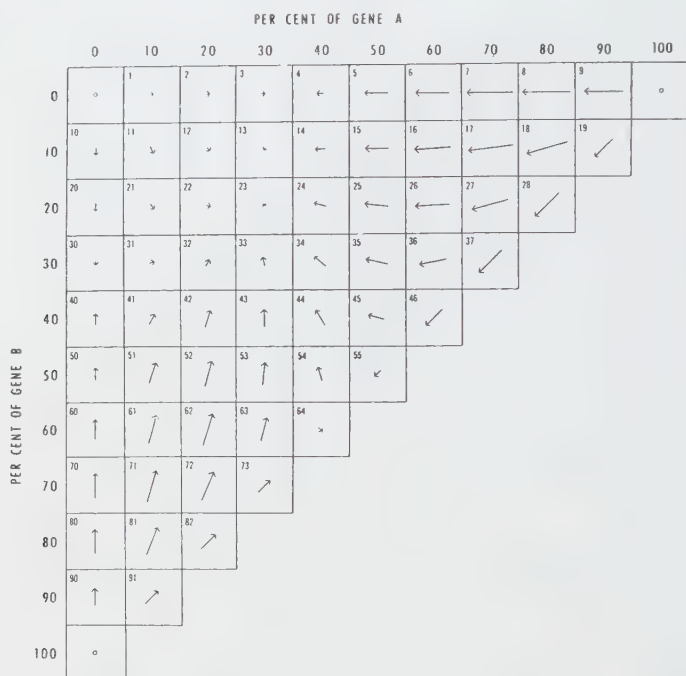


Fig. 2 Graphic representation of the vectors of table 3. The magnitude of the vectors has been exaggerated so that on the scale of the framework of the chart, each arrow represents the equivalent of about 100 years of selective change.

of the vectors would be proportionally changed also. So no certainty can be given that the absolute magnitude of any selective factor has been determined or is determinable in this way.

The final selective values on which table 3 and figure 2 are based are then; OO, zero (the point of reference); OA, plus 15%; OB, plus 5%; AA, minus 6%; AB, plus 3%; BB, minus

4%. In figure 2 the individual squares for which vectors have been calculated are numbered for ease of reference.

The mathematical model

The vector system in general focusses upon a point at 25% A gene and 15% B gene, with very small vectors close to the focus and large ones at a distance from it. The magnitude and detailed direction of the vectors are of complicated pattern, however, a fact which led to many hours of rechecking in search of arithmetical errors. In graphic representation the vectors appear more consistent than in tabular form. The distribution of vectors along the line A-O (i.e., where B is absent or very rare) has already been discussed. A population may be located anywhere from square 1 to square 4 without encountering a vector in either direction stronger than one-fourth of one per cent per generation. As the B gene increases, the vectors for A become stronger, tending to restrict variation in frequency of A. In square 4, for instance, the vector for the A gene is minus .26%; in square 24, minus .48%; similarly in square 2 the vector for the A gene is plus .10%, in square 24, plus .15%. This phenomenon, due ultimately to the complications introduced by the incompatibility effect, offers a possible explanation for the less range of A gene frequency at high B levels than at low B levels. The downward vector for the B gene in square 42, just above the upper limit of B frequencies, is approximately equal to the downward vector for A in square 5, which is virtually the upper limit for the A gene.

The vectors for the B gene in combination with O are not as anticipated in the beginning. The first examination of the distribution suggested that B vectors where the A gene was absent should be almost entirely negative, so as to prevent the development of B in a population originally homozygous for O. Instead we find strong plus B vectors in squares 10 and 20, easing off at square 30, and strongly negative at squares 40 and 50. It was not found possible to avoid this by

manipulation of the quantitative value of selective factors except at the cost of disrupting the successful parts of the vector system. Along the O-B axis there is found one outlying group in square 30 (the Caraja Indians of Brazil) which on first examination was thought to be possibly an erroneous report. Perhaps they actually represent a unique achievement of O-B equilibrium in the absence of A. (To say this is to admit that "newness" of genes is involved, that certain combinations have not been fully exploited, in contrast to our previous statement of principle.) But such an isolated development of the B gene, might very well be a comparatively new independent mutation. The principal upward vectors of B are at low A levels (squares 11, 12, 21) and at high A levels (squares 17, 18, 19, well outside the limits of recorded populations). The greatest weakness of the vector system is in squares 21 and 31, where we would wish to see stronger plus-A vectors to account for the lack of populations there. The vectors in square 31, for instance, are by no means strong enough to account for the fact that this is an "empty" area on figure 1b. Other marginal empty or nearly empty areas such as squares 42, 14 and 5, have considerably stronger vectors.

SOME HISTORICAL CONSIDERATIONS

The absolute magnitude of the vectors, as we have said previously, cannot be determined in any *a priori* fashion; the pattern here shown could be essentially retained by a system in which all vectors were greater or all less. However, it is interesting to consider the magnitudes suggested here, and see whether they are seriously inconsistent with historical probabilities. Any such vector system as we have proposed will be always interacting with genetic drift. Small or isolated populations will be continually scattering as the result of drift, but in more copious populations (of the magnitude of most European groups in the last millenium, or of the larger sedentary groups in Asia and Africa), genetic drift will be quite ineffective, and selective pressures will act with great constancy. (An interesting analogy may be made with

the respective effects of Brownian movement and gravity on suspended particles of different sizes.) All such populous groups should then tend inexorably to move towards the final equilibrium point at about 25% gene A and 15% gene B. Is it then possible for groups of this magnitude to be at the present time as different from one another as they now are, in view of this selective pressure? Most of these major population groups, White, Mongoloid and Negro alike, are located in squares 12, 13, 22 and 23, with very low vectors. In square 13, the typical location of most North European populations, the vectors are minus .05% for the A gene and plus .10% for the B gene. Twentieths and tenths of one per cent do not make for very rapid changes, particularly in a species which takes a century to run through 4 generations. A group under the selective pressure at square 13 would require 2,500 years to change its frequency of the B gene by 10% and its frequency of the A gene by 5% — provided the vectors remained constant. (The vectors actually would decrease as the group approached the central equilibrium point.) The magnitude of the time factor here seems adequate to indicate that the present divergencies of the major population groups could be explained as vestiges of more marked peculiarities in the past, which had developed during the period when the ancestors of even our largest modern populations lived under conditions of low population density which favored genetic drift. Such population densities need not be less than those of the Pre-Columbian New World, in which scatter due to genetic drift is very evident. If we assume that the Old World has overall population densities of this same magnitude up to the beginning of the Neolithic at least, the primitive condition of wide random range of blood group frequencies is not too far in the past to account for the diversities of the now more populous groups, even though constant selective factors may have been standardizing blood group frequencies since population levels increased. In contrast to the extreme slowness with which selective pressures would act in the "occupied" area of figure 1, are the high vectors for other parts of the

range. A population located in square 9 (that is, an A population which had acquired 10% of the gene O) would take only 1,000 years to reach square 4, under the strong selective pressure to which it would be subjected.

Another interesting problem in constancy of values is presented by the oft-cited case of the similarity in blood-group frequencies of Gypsies and Hindus, after long separation. Coon states that the separation is of approximately 1,000 years standing. If the Gypsies started at square 31, with the vectors there assigned, in the course of 1,000 years they would, if selective pressure alone was acting (though undoubtedly genetic drift would have played a part also) have changed to the extent of 6.8% in the A gene and 2.4% in the B gene; by no means enough to equate them with the Hungarians, with whom they are always compared, or other European populations. Incidentally, the group from which they separated would have tended to change correspondingly in the same length of time; so that similarity of fractions of a group long separated is no evidence against change in blood group frequencies in time, if the changes are determined by factors intrinsic to the genotypes.

Another case which tests the magnitude of the vectors is that of the Blackfoot Indians, who, according to our vector system, are presently in a position where selection alone would tend to reduce their percentage of the A gene by 1% per generation, or 10% in 250 years. Whether their situation is a plausible one will depend on the extent to which genetic drift has been able to act on them in the past. In any event, they would represent an extreme case. The tribe, according to Chown and Lewis ('53), consisted of about 10,000 members in the 18th century; a hundred years later their numbers were greatly reduced; how long previously they had held a high population level is not known. In a group of 10,000 genetic drift is not very effective; each generation's sample of 20,000 genes would reproduce the previous generation's percentages with a probable error of only .24%. This would make it diffi-

cult for the selective vector, three or 4 times this magnitude, to be reversed or neutralized for even a generation. If the populousness of the Blackfoot was not of long standing, and if the tribe had arisen by rapid breeding up of a small genetically drifting group, an unusual run of luck for the A gene could have placed them in the position they now hold. Since in fact they are an extreme group out of many, they are entitled to a submarginal probability. All these cases suggest that the magnitude of the vectors here proposed is not impossibly great, though perhaps somewhat too large.

The vector system then seems to be satisfactory according to the requirements originally set up for it. It demonstrates that it is possible to explain the overall range of blood group gene frequencies found in the human species by the action of selective factors inherent in the blood group genotypes themselves. Some readers may rightly conclude that the apparent limitations on the range of human blood group gene frequencies do not require explanation, or at least do not require explanation so badly that we must be forced to leap into such extremely hypothetical mathematics to solve the problem. However, the dubious and fictitious character of the hypothesis presented here makes it all the better company for various other entirely unprovable theories regarding the origin of the present A-B-O frequencies. At least an attempt has been made to make the system as far as possible absolute and not contingent; we have rejected, for instance, Ford's suggestion that the maintenance of somewhat different A-B-O frequencies in different races is due to differences in other features of the genetic makeup, which cause the blood group genes to reach slightly different points of equilibrium in different races. And of course, no consideration has been given to the possibility that the various blood group phenotypes are of different selective value in different environments. Anyone who wishes to introduce these possibilities can no doubt fit a scheme to the facts far more closely than we have, since he will be under no limitations whatsoever.

Extrapolation toward the origin of the genes

It is clear from an examination of the vector system that under such rules the range of values finally attained by the human species will be the same regardless of whether all three genes were present in the basic human population (whatever and whenever that was) and of what order they appeared in, if they appeared at different times. The same configuration could be reached by starting from A or B as from O. There has always been an inconsistency felt between the average frequencies of the A-B-O genes in man, which certainly indicates O as the most likely original gene, and the fact that A is the only gene common to man and all 4 of the great apes. So it will be interesting, by way of examining possible ways in which selective vectors might function, to choose as an example the case in which A was the original gene. The historical reconstruction would run somewhat as follows: An all-A population would be extremely vulnerable to change if either the O or the B gene became established, because of the selective advantage of OA and AB over AA. (The term "became established" is used advisedly. Even in the presence of selective advantage, a gene may not survive the first generations following its appearance. The likelihood of successful establishment of a gene—a bridgehead this side of oblivion, so to speak—will be much less than the mutation rate.) If a mutation to gene O occurred in the A population, it would, after becoming established and going through the slow early stages of increase to a level of 1%, have a vector of plus .21% per generation which would continually increase as gene O became more abundant. The selective advantage of OA would be very great at first since incompatibility effects would not appear until OO genotypes were encountered with some frequency. Two hundred and fifty years would then be required to bring the O gene up to 5%; 100 years to carry it from 5 to 10%; and 1,000 years to take it to 60%, where some population units would begin to hesitate and lag as genetic drift countered the lessening selective pressure. There would be, that is, a sudden break

in a stable condition, very rapid change for a period, and then settling down in a new equilibrium.

If the first mutation to become established in the original A population were B, the course would be similar, but with the rate of reduction in the percentage of A less rapid. As long as the A and B genes only were present, the tendency would be towards an equilibrium in which the B gene would be slightly in excess. At any time, however, the introduction of O would cause the trend to turn towards the final equilibrium point at 15% B gene. If the O gene did not appear till B had become commoner than this, there would be a stage of decline in both A and B.

If O was the first mutation from A, then B became established probably in some population with both the O and A genes. If the establishment of B was at all delayed, it would probably not occur until some populations were near or beyond 60% O gene. The vectors in squares 14 to 17 are so strongly downward for A and so slightly favorable to B that any groups in this area would be rushed through towards O with little opportunity to stray upwards in B. Then the most likely opportunity for B to develop — i.e. the strongest upward vectors for the B gene — would be in groups which had reached 80 or 90% O gene. Since the consensus of distributional evidence is that the B gene, at least the earliest and most successful establishment of it (leaving aside local developments from scattered B mutations) is later than the O gene, it seems most likely that it got its start in low-A fractions of a world population already well diversified in O-A frequencies in about the range now found. These first O-A-B populations could be "proto-Mongoloids."

A "polyphyletic" interpretation is also possible; the O and B mutations may have originated in populations which were for a time isolated from one another, producing two main divisions; an A-O division, and an A-B division; either or both may have gone to their respective equilibrium points at some time, then come in contact with one another later. The A-B strain could be designated "proto-Pre-Dravidian-

and-Ainu." The basic difference between the latter two possibilities is whether, of the present high-B groups, the Mongoloid or non-Mongoloid contributed the B gene.

Further detailed speculation on the basis of such a tentative scheme would be out of place. Numerous developments will undoubtedly necessitate the revision of any values for selective effect guessed at now. More careful examination may reveal other incompatibility reactions which would replace or modify the selective values now proposed. The magnitude of the incompatibility between A and O may be better defined in the future. The degree of complication which may result in these matters is shown by the demonstration that incompatibility between parents in the A-B-O system affords some degree of protection against the development of hemolytic disease in response to Rh-incompatibility in the same family (Levine, '43). If this phenomenon can be accurately defined it may contribute also to the selective pattern, in a way correlated with the Rh-gene composition of the population in question. Another probability is that the various subtypes of the gene A, which differ in the vigor of their serological reactions, may well differ also in the degree to which they are affected by incompatibility or other selective phenomena. Possibly the only permanent contribution of such a premature hypothesis as presented here will be to point out that any system of selective factors of whatever kind must eventually be consistent with the limitations of the world range of A-B-O frequencies. Once the hypothesis of absolute non-selectivity of the A-B-O blood groups has been abandoned, through necessity or choice, even if in respect to one genotype only, we must assume that the genes are in a state of dynamic equilibrium, and that the world range of frequencies in respect to the A-B-O genes is an essential piece of evidence in ascertaining this equilibrium.

DIRECT STUDY OF A-B-O SELECTION

Numerous attempts have been made to demonstrate selective effects with respect to blood groups by statistical means.

The possibility of differential survival in the pre-natal period has already been approached by study of the precise frequencies of children produced by matings of various types. In the case of the A-B-O blood groups difficulty is introduced by the fact that the genotype AA cannot be distinguished from OA, or BB from OB. If selection is such as to favor heterozygotes over homozygotes, the selection effects will tend to cancel out, as far as phenotype is concerned. In the case of the M-N blood groups, where all phenotypes are immediately distinguishable, very strong evidence of differential survival of the heterozygous embryo (about plus 20%) has been adduced by some workers. (For an excellent account of this and other selective effects of blood groups, see Race and Sanger, '50; also Race, '50).³ However, these results have been challenged by other workers as due to constant errors in technique. The possible scope of such errors, as claimed by immunologists engaged in disputes with one another (Wiener, '43), is very considerable and somewhat disillusioning to the anthropologist. Thus any selective deviations of the magnitude which we have hypothesized are likely, even if detected, to be challenged for a long time in the immunological field, where the anthropologist is not properly entitled to take sides.

The question of postnatal mortality differences presents other difficulties (aside from the confusion of homozygotes and heterozygotes). Mortality rates and causes in civilized peoples are very different from those of primitive and pre-historic peoples, and we cannot assume that any differential mortality rates which were effective through most of the history of the race are still effective at the present time. In fact, with mortality in the age period 0-35 years reduced to little more than 5% as compared with a probable 50% or more in former times, it can hardly be said that differential mortality, as far as it affects the production of the next generation, exists at all among civilized peoples; and selec-

³ As this goes to press, Neel ('54) has published a paper in which the most recent work on this subject is ably summarized.

tion cannot act in the absence of mortality. Any study of differences in blood group frequencies at different ages in a modern population, then, can hardly show appreciable changes with age except in the older age groups from which some proportion of individuals have actually been eliminated; and even here the mortality causes involved may be totally different from those which decimated the young and adolescent in prehistoric times.

Still another way in which selective effects might be exercised is through differences, not in individual survival, but in fertility. Obviously a slightly higher fertility of any A-B-O genotype will have the same effect on the gene frequencies of the next generation as if more individuals of that genotype were present and reproducing at average rate. The possible complexity of this sort of selection is shown (Bryce et al., '51) in a study suggesting that the genotype AB is produced in slightly less than expected ratios by A and B mothers, but that the surviving ABs (at least if female) reverse the effect by their higher fertility. Obviously the selective resultants can be very complicated, and require much study.

It may be adequately argued that the present paper has not clearly proved that the A-B-O blood group genes are selective. However, it may be pointed out that neither has anyone ever proved that they are *not* selective. Early in the history of the study of blood groups, it was decided with fairly universal concurrence that the blood group genes had no selective value. When analyzed, the reason for this decision appears to be the rather *a priori* one that since the agglutinogens of the blood did not come into any very obvious or direct contact with the external environment, they *did not seem to be the sort of thing that would be selective*. By continuous repetition this assumption has attained the status of a dogma, so that the entire burden of proof is placed on those who venture to contest it. In part even the dogma has been cherished as a weapon in a faintly personal contest between those specially versed in immunology and others

specially versed in other branches of physical anthropology. Altogether too many statements about the selectivity or non-selectivity of various traits have been preceded by the deadly phrase "of course." It would be more advisable to keep an open mind on all such matters, and let the burden of proof fall equally on both parties to the contest.

SUMMARY OF THE ARGUMENT

It is pointed out that the frequencies of the A-B-O blood group genes, which vary considerably among various human races and subraces, are nevertheless subject to certain limitations. Of the total possible range of variation, only about one-fifth is found to be occupied by human groups now living. Those areas of the range representing less than 50% O gene, or an excess greater than 10% of the B gene over the A gene, are only marginally occupied.

The traditional view is that a complete lack of selective value on the part of the A-B-O genes has made possible the maintenance, from the time of inception of the species, of a basic gene formula which has developed a moderate degree of diversity but has never varied radically from its original proportions.

A suitable explanation for the origin of some diversity in frequency of the A-B-O genes has been seen in the workings of genetic drift, by which entirely random factors may produce alteration of gene frequencies, especially in small populations. Examples of this phenomenon may be seen in the diversity of blood group gene frequencies within subgroups of a given race.

A certain paradox becomes evident, however, when the evidence for genetic drift is examined carefully. The most striking case is the variation in frequency of gene A within the aboriginal populations of North America. These tribes include examples of A gene frequencies which are absolute maxima and minima for the human species. Yet these groups are certainly racially akin to one another within the limits allowed to major races, and can hardly be considered to con-

stitute an "old" race in the sense that they have had a maximum length of time in which to develop A-B-O gene differences by genetic drift. If genetic drift has acted so strongly on a relatively local basis and during a limited time, why has it not produced even more striking diversity in the species as a whole during the entire period of its evolution? It is therefore suggested that positive factors of some sort act to restrict variation in the frequencies of the A-B-O blood group genes, so that increase of time and opportunity does not allow genetic drift to go beyond certain limits.

Since a reasonable explanation for such a limitation is the existence of selective factors discriminating against certain genotypes (in this case probably the homozygous types AA and BB), the idea of a balanced selective system maintaining A-B-O gene frequencies was entertained.

Consideration was also given to evidence that the genotype AO is acted against by some form of maternal-fetal incompatibility. Examination of the ultimate effects of such a phenomenon emphasizes the fact that the presence of a single selective effect on any one of the A-B-O genotypes would introduce a disturbing factor into the whole system such that counteracting selective effects on the same or other genotypes would be necessary to maintain stability of gene frequencies for any length of time.

It appears to the present author that there is no middle ground between the doctrine of complete non-selectivity as an explanation for the persistence of a heterozygous condition for many millenia, and the alternative doctrine of a dynamically balanced set of selective factors which maintains the diversity of the gene formula within certain limits. If non-selectivity breaks down at all, it breaks down completely. On the basis of the evidence above it is concluded that the latter doctrine must be held.

On this basis experimental calculations were made, to show that a system of balanced selective effects could be made to explain in some detail the limitations on the present range of A-B-O gene frequencies. It is shown that on this basis

gene A, which is common to all the highest primates, could very well have been the original blood group gene of man.

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THE RELATION OF LEAN BODY WEIGHT TO METABOLISM AND SOME CONSEQUENT SYSTEMATIZATIONS. By Albert R. Behnke. *Annals of the New York Academy of Sciences*, Vol. 56, Art. 6, pp. 1095-1142. New York, 1953.—The concept of lean body weight is one with which Captain A. R. Behnke (MC), U.S.N., is thoroughly identified, for his earlier work published in 1942 led to the use of the specific gravity technique by the Minnesota Group, J. B. Hamilton and others. In the present photo-offset study (which won the A. Cressy Morrison prize in 1952) Doctor Behnke related lean body weight to basal metabolism, and finds a very close fit. He notes a high (0.94) correlation between lean body weight and surface area, and suggests that with lean body weight as a reference standard, the usual sex difference in basal metabolic rate tends to disappear. Lean body weight, which is thought not to change during adult life (though gross weight may) thus becomes one property of the individual to which a multitude of other variables such as total body water can be related. Of especial interest is the index $\frac{LBW}{H^2}$ which “eliminates the factor of stature in the comparison of weights” and obviously and immediately serves as a measure of body build, or rather of relative muscularity. However, while lean body mass or its weight (lean body weight) may be equated with the “active protoplasmic mass,” in the adult it is necessary to consider also the metabolism-stimulating effects of certain of the steroid hormones. And when this is done, the sex difference in metabolic activity (for example) is not quite as simply explained as this most admirable work would have. — Stanley M. Garn.

A BLOOD GROUP GENETICAL SURVEY IN AUSTRALIAN ABORIGINES

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The absence of group B in unmixed Australian aborigines in South Australia and the Northern Territory was demonstrated in the numerous early surveys made by Professor J. B. Cleland of Adelaide. In an even earlier survey Dr. A. H. Tebbutt of Sydney had found group B in unselected natives congregated at Barambah Aboriginal Station about 100 miles north of Brisbane in the State of Queensland. All the early A-B-O blood group surveys in Australian aborigines have been tabulated and the distribution of group B discussed by Birdsell and Boyd ('40), and by Wilson, Graydon, Simmons and Bryce ('44).

Birdsell and Boyd reported the A-B-O groups for 805 aborigines and the M-N types for 730, while Wilson et al. presented A-B-O and M-N results for 649 natives in different parts of Australia. Another group of 54 not included in the main series was located at Groote Eylandt in the Gulf of Carpentaria.

Simmons, Graydon and Hamilton ('44) reported the results of tests for the Rh factor using what was subsequently proved to be a standard anti-Rh₀ serum. All of 281 aborigines who had originated in widely scattered places were shown to be Rh positive. Simmons and Graydon ('48) presented the Rh gene frequencies for 234 Australian aborigines. The *R^z* gene

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³ With the field collaboration of Dr. L. W. Alderman (Darwin); Dr. J. R. Heath (Elsey Station); Professor J. B. Cleland, Mr. B. D. Hill (Yuendumu); Professor J. B. Cleland (Ernabella).

was demonstrated in this series, in apparently a patchy distribution over various Australian states.

Sanger, Walsh and Kay ('51) tested 178 aborigines at Bathurst Island, Cherbourg (Barambah) and at Woorabinda. In the M-N-S system none of the 178 blood samples showed the S antigen. No example of Lutheran (Lu^a) was found. In 98 Bathurst Islanders 34.7% were P positive. They considered that whole blood samples gave unreliable results for the Lewis (Le^a), Kell (K) and P antigens because of lability of antigens on transport from the field.

Simmons, Graydon and Birdsell ('53) have given a summary of their serological findings to May, 1953, for the first 395 aborigines tested in an extensive field survey conducted by Birdsell in Western Australia. Tests made in the survey cover A-B-O, M-N-S, Rh, P, Le^a , Fy^a , K, Lu^a and He blood groups. In addition, tests made on 125 random blood samples for the sickle-cell trait showed no evidence of this characteristic. A similar finding for 72 North Queensland aborigines of which 57 were recorded as unmixed, has been reported by Horsfall and Lehmann ('53). The final serological results of Birdsell's investigation will be published some time after the field survey concludes about the middle of '54.

The material reported in the present paper has been gathered together between '49 and '52, and concerns 167 aborigines living in the Northern Territory and South Australia. Most of the samples tested were sent to us by University of Adelaide Anthropological Expeditions to Ernabella and Yuendumu in '50 and '51 respectively, and the remaining small number of samples were collected in Darwin and at Elsey Station. The technical methods employed were those described by Simmons, Graydon, Semple and Taylor ('51).

RESULTS AND DISCUSSION

A-B-O groups and subgroups

The results have been presented in tables for the various localities where samples were collected, arranged in order from north to south.

In the whole series only one sample of group B was found and that was collected from a native in Darwin Hospital where no genealogies were taken by the hospital staff, and consequently it may have been from an undetected hybrid.

The high group O ($O = .87$) in the north at Darwin and at Elsey Station reflects the high group O frequency previously found in Darwin ($O = .778$) and on Melville and Bathurst Islands ($O = .826$) by Wilson et al. ('44).

Gene frequencies calculated from the figures presented are for Yuendumu (93), the only substantial group: $A = .312$, $O = .688$ and for the total of 167: $A = .254(5)$, $O = .741(5)$, $B = .004$. Surveys made over wide areas of Australia by Birdsell and Boyd and by Wilson et al. resulted in the following gene frequencies respectively:

$$(805): A = .260, B = .014, O = .729.$$

$$(649): A = .251, B = 0, O = .749.$$

In the present series no example of subgroup A_2 was detected in 74 group A blood samples.

The M-N types and S subdivisions. The gene frequencies calculated from the figures presented in table 2 are:

$$\text{Yuendumu (91), } m = .280, n = .720.$$

$$\text{Total (165), } m = .255, n = .745.$$

No M or N variants were detected in the 165 blood samples tested. In the small series of 32 tested at Ernabella, $n = .94$, a figure which suggests a pocket of very high n .

M-N frequencies presented by Birdsell and Boyd and by Wilson et al. were respectively:

$$m = .178, n = .822.$$

$$m = .297, n = .703.$$

One S-positive individual living at Yuendumu was detected in the series. All attempts to get a further blood sample from this person failed as there had been confusion in identification. As this is the only example of the S antigen found to date in Australian aborigines, it is thought that it is probably of fairly recent introduction.

The Rh types. The Rh types are presented in table 3. In the calculation of gene frequencies it is necessary to assume

the presence of three genes only in the Yuendumu series, and four in the total series. Other evidence suggests that R^z in Yuendumu, and r' in both may be present in low concentrations undetected in these small series.

The calculated gene frequencies are:

Yuendumu (93): $R^1 = .576$, $R^2 = .408$, $R^0 = .016$.

Total (167): $R^1 = .541$, $R^2 = .371$, $R^0 = .072$, $R^z = .016$.

TABLE 1

A-B-O blood groups in Northern Territory and South Australian aborigines

LOCATION AND DATE	NUMBER TESTED	BLOOD GROUPS		
		O	A ₁	B
Darwin N.T. 13. 3.51; 5. 2.52.	30	23	6	1
Elsey Station, N.T. 5. 5.49.	12	9	3	0
Yuendumu, N.T. 3. 9.51.	93	44 47%	49 53%	0
Ernabella, S.A. 28. 4.50.	32	16	16	0
Totals	167	92 55.1%	74 44.3%	1 .6%

TABLE 2

M-N types and S subdivision in Australian aborigines

LOCATION	NUMBER TESTED	M-N TYPES			PROPORTION OF SAMPLES S- POSITIVE
		M	MN	N	
Darwin	30	4	12	14	0/30
Elsey Station	12	4	1	7	0/12
Yuendumu	91	5 5%	41 45%	45 50%	1/91
Ernabella	32	0	4	28	0/32
Totals	165	13 7.9%	58 35.2%	94 57%	1/165 .6%

The figures in the tables and in other surveys suggest that there is an Rh_2 gradient increasing from north to south, i.e. from Darwin and Bathurst Island to Yuendumu and Ernabella.

The Rh gene frequencies presented by Simmons and Graydon ('48) for 234 aborigines of which about one-half originated in Queensland were:

$$R^1 = .564, R^2 = .201, R^0 = .085, r' = .129, R^z = .021.$$

TABLE 3

Rh types in Australian aborigines

LOCATION	NUMBER TESTED	Rh TYPES						
		Rh_1Rh_1	Rh_1Rh_0	Rh_2Rh_2	Rh_2Rh_0	Rh_1Rh_2	Rh_1Rh_z	Rh_0Rh_0
Darwin	30	14	5	0	0	8	2	1
Elsay Station	12	7	2	0	0	2	1	0
Yuendumu	93	24 26%	2 2%	12 13%	1 1%	54 58%	0	0
Ernabella	32	4	4	4	2	18	0	0
Totals	167	49 29.3%	13 7.8%	16 9.6%	3 1.8%	82 49.1%	3 1.8%	1 .6%

Recent tests on blood samples from Western Australian aborigines have shown that both Rh_0 (D^0) variants and rh' exist in these natives. The differentiation was made by means of the anti-globulin test.

Other observations. Table 4 presents a summary of eight other series of tests performed.

At Yuendumu there were 4 individuals whose blood agglutinated in variable strengths with potent anti- Rh_0 sera. These 4 Rh_0 (D^0) variants were therefore of "high-grade." No example of rh^w (C^w) was detected in 167 samples. In tests for the P antigen 91/140 (65%) were recorded as P+. There was good correlation between the Lewis blood group and the A, B or H salivary secretion. In Lewis tests 12/164 (7.3%) were Le (a+) while 4/124 (3.2%) of the same individuals

TABLE 4

Summary of other tests performed on Australian aborigines in present survey

LOCATION	Rh ₀ (D ^u) VARIANTS	rh ^u (C ^w)	P ⁺	LEWIS Le (a+)	SALIVA		DUFFY Fy (a+)	KELL K+	TASTE REACTIONS	
					S	SS			Taster	Non- taster
Darwin	0/30	0/30	6/15	2/30	15	0	15/15	0/15	31	4
Elsey Station	0/12	0/12	..	2/9	..	..	..	..	..	..
Yuendumu	4/93	0/93	63/93	7/93	75	2	34/34	0/43	23	62
Ernabella	0/32	0/32	22/32	1/32	30	2	..	..	23	9
Totals	4/167	0/167	91/140	12/164	120	4	49/49	0/58	77	75
	2.4%	0%	65%	7.3%	96.8%	3.2%	100%	0%	50.7%	49.3%

were non-secretors (ss). All of 49 individuals tested were Fy (a +) while none of 58 were K +. In P.T.C. taste tests 77/152 (50.7%) were recorded as tasters.

At the time of sending these earlier observations to press the Birdsell Expedition has sent in over 1200 blood samples from widely scattered areas in Western Australia; thus a great deal of genetical data is being accumulated for publication after the survey concludes and an analysis of the results has been made.

ACKNOWLEDGMENTS

Most of the blood samples studied were collected from aborigines living at Ernabella and Yuendumu during '50 and '51 by University of Adelaide Anthropological Expeditions. These expeditions were financed largely by the Wenner-Gren Foundation for Anthropological Research, Inc., and by the University of Adelaide. The authors would also like to especially acknowledge the most generous co-operation given to them by Professors A. A. Abbie and J. B. Cleland of Adelaide.

SUMMARY

Blood samples from 167 Australian aborigines living in the Northern Territory and South Australia have been tested for the A-B-O, M-N-S, Rh, P, Le (a), Fy (a) and K blood groups, and from the results obtained various calculated gene frequencies are presented. P.T.C. taste tests were also carried out on 152 aborigines.

The results indicate again that over this vast country there are often considerable gene frequency variations in different localities. A most extensive genetical survey is at present proceeding, and the results will be presented at a later date.

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BRIEF COMMUNICATIONS

ON THE EDUCATION OF THE PHYSICAL ANTHROPOLOGIST

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The education of the physical anthropologist, in those institutions granting the doctoral degree, has been that of an anthropological generalist, with some specialization in human biology. With slight variations, depending on the university considered, the candidate for the Ph.D. in physical anthropology was first expected to demonstrate proficiency in archaeology, social anthropology and regional cultures. The bulk of his required courses was, of necessity, concerned with subjects other than physical anthropology, anatomy, and related studies. This scattering of emphasis meant that the physical anthropologist, newly the recipient of the advanced degree, was apt to be deficient in biology and in the many methods and techniques needed by physical anthropologists today.

The degree-requirements adhered to by the institutions under discussion were not the result of whimsey, nor were they entirely unrealistic. Until recently there were few job opportunities for physical anthropologists as such. Even today, it may be added, less than a dozen American physical anthropologists derive their incomes from the teaching of physical anthropology alone. Rather, the rules for graduate studies were aimed at the production of generalists, capable of teaching diverse courses in anthropology, and therefore more generally employable.

But as things have worked out, relatively few physical anthropologists have elected careers teaching general anthro-

pology. A sizeable fraction have become professors of anatomy. Another large group have become employed in applied physical anthropology, a field scarcely 10 years old. And an increasing number have gravitated into human development, human genetics, and medical and dental research. For all of these, the conventional training could well have been supplemented by training in physiology and endocrinology, more adequate preparation in statistics and genetics, and considerably more experience with research methods, including experimental anatomy and scientific instrumentation.

The problem arises of how to provide these desirable features for graduate students of the present and future. Simply cutting down course requirements in other subjects is not enough. In the first place, little time actually would be gained. And secondly, and more important, this expedient would come dangerously close to cutting off from physical anthropology the very background in anthropology that makes it a distinctive field of investigation. Obviously, the only practicable way of solving the problem is to expand the training period, increasing the number of required courses, without minimizing the training in anthropology proper. Interrogation of recent graduates shows that an informal trend to this effect is now in progress. Fewer students "complete" their education with the traditional minimum of 8 full courses, and additional training in the biological sciences is now generally recommended. A formal expansion of the course of studies would seem to be indicated.

Even so, there is the problem of attaining sufficient experience in methods and techniques. Once anthropometry was *the* technique of physical anthropology, and each institution offered a field course or its equivalent. Today, the techniques of physical anthropology include serology, radiology, microchemistry, and statistical methods involving printing tabulators and electronic calculators. No one university now offers anthropologically-oriented training in all of these research techniques. Ideally, perhaps, there should be an Institute of Physical Anthropology, or (closer to practicality) alternate

Wenner-Gren Summer Seminars could be devoted to training sessions in these various methods. But at the present time the resourceful graduate student (or his advisor) can make use of the facilities available in different institutions and the opportunities extant at many research institutes, to round out the sparse training in methods available at just one university alone.

The objection may be raised that the traditional education in physical anthropology is adequate. Do not most physical anthropologists have jobs? To this we may counter that education adequate for the past is not necessarily adequate for the present, and that the demands of today can not be met by training designed for yesterday. It is also possible to suggest that the additional training suggested here, while desirable in theory, could be attained by the physical anthropologist *after* graduation, and on-the-job. Since few physical anthropologists have managed to employ investigative techniques or methods of analysis not already familiar to them by the end of their graduate careers, it is possible to doubt the practicality of such post-doctoral additions. Besides, it is not proper that the scholar with a Ph.D. should be the master of the methods and techniques he may be expected to use?

Physical anthropology today demands of the physical anthropologist background knowledge in biology and investigative techniques not possessed by his predecessors of former years. Moreover, the contemporary physical anthropologist is most likely to occupy a position teaching or conducting research in the biological sciences. While nothing would be gained by reducing his background knowledge in anthropology, much benefit would be attained by increasing his knowledge of biology. And to keep abreast of the expanding number of methods and techniques, he should have the opportunity to learn them before attaining the degree. Such alterations in the curriculum and in the scope of graduate training are needed for the education of the contemporary physical anthropologist.

A NOTE ON THE PALAEOPATHOLOGY
OF ONTARIO

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TWO FIGURES

Osteological remains from two sites recently excavated in Ontario by the Royal Ontario Museum of Archaeology have yielded interesting pathological specimens. These were studied by Dr. R. I. Harris, graduate lecturer in surgery at the University of Toronto, and an eminent orthopedist, to whom the writer is deeply indebted for the information submitted here and for his kind permission to publish it.

Of the two sites referred to, the first to be excavated and by all means the most prolific of osteological material, was an ossuary burial of the Huron Indians, in Tiny township, Simcoe county, opened in 1947-48 and reported in *American Antiquity* (Kidd, '53). This was an immense grave containing an estimated 1000 or more individuals of all ages; it is believed to be the burial witnessed by a Jesuit missionary in 1636 at a place called Ossossané, which gives it the distinction of being one of the few documented Indian sites in the Province. The second site was that of a Late Woodland people near Chatham, in Kent county, in which a group of nine individuals was the most significant feature for the purposes of this paper. It is known as the Krieger site, and a general report upon it will appear shortly. Taken together, these two sites provided skeletal remains from areas widely separated geographically, and temporally by perhaps as much as 1000 years.

Doctor Harris was not able to examine all the Huron material in detail, due to its great volume, but he saw a representative portion of it, including a collection of obviously pathological specimens which had been segregated in the field. In this collection, he found two instances of Struempell-Marie disease, which he describes as follows:

"The first consists of a sacrum and its associated right ilium (fig. 1 a). The important finding in this specimen is the complete obliteration of the right sacro-iliac joint and the fusion of the ilium to the sacrum by a bridge of bone. There is no evidence of destruction of bone. The radiograph (fig. 2 a) shows that the cartilage of the synchondrosis has been completely absorbed and replaced by bone. The ilium is fused to the sacrum to form one solid bony mass. The second specimen consists of a sequence of six dorsal vertebrae (fig. 1 b-c) probably about the middorsal region. These are completely fused to one another by bone bridges resulting from ossification of the longitudinal ligaments and the ligamenta flava. Two rib stumps are present on the right side at the upper end of the specimen and a single rib stump is present on the left side, also at the upper end of the specimen. In all three ribs, the costovertebral and the costotransverse articulations are obliterated and bony fusion of the ribs to the vertebrae has taken place. The radiograph (fig. 2 b-c) shows the bony bridging from vertebral body to vertebral body (bamboo spine) produced by ossification of the longitudinal elements. This is the characteristic feature of Struempell-Marie (ankylosing) spondylitis, while the lesion of the sacro-iliac joint is likewise characteristic of the ailment.

"Ankylosing spondylitis or Struempell-Marie spondylitis is a disease of somewhat rare incidence closely related to rheumatoid arthritis but nevertheless distinct from the latter disease. It involves the sacro-iliac and spinal joints, commencing in the former and progressing steadily upwards to the neck. It sometimes involves the shoulders and hips but almost never the small joints of the hands and feet as is so common in rheumatoid arthritis. The lesions in the spine progress to bony fusion in a characteristic manner and it is this feature which makes it possible to recognize unequivocally the lesions in the specimens from Ossossané. It is a disease confined almost exclusively to males in contrast to rheumatoid arthritis which predominantly is a disease of females. These remarkable specimens are indisputable evidence that the Huron aborigines of Ontario suffered from this first cousin to rheumatoid arthritis and they give us a grim picture of the disability which must have handicapped the original owner of these bones, faced with the necessity of earning his livelihood by hunting, fishing and primitive agriculture."

Since the Krieger material was limited in quantity, Dr. Harris was able to examine all of it. He found only one individual to have been afflicted in any way; this was skeleton no. 7, the remains of a "strong, active male, at least 50 years of



Fig. 1 Two pathological specimens from a Huron ossuary. (a) Sacrum and associated right ilium fused to one another at the right sacroiliac joint which is completely obliterated. The cartilage of the synchondrosis has disappeared and the two bones are fused to one another by a bony bridge. (b) Antero-posterior view of six fused dorsal vertebrae which show ossification of the longitudinal ligaments. (c) Lateral view of six fused dorsal vertebrae to show ossification of the longitudinal ligaments and fusion of the ribs to the spine.



Fig. 2 Radiographs of specimens shown in figure 1 and in same relative positions.

age" and probably about 5 feet 7 inches tall. Dr. Harris describes the evidence for its two congenital anomalies as follows:

"The first and most obvious abnormality is an asymmetrical distortion of the skull which involves all the bones of the face. The right side is larger than the left, and this is especially marked in the mandible. As a result, the midline of the face is a curved line convex to the right and a line joining the middle orbital fossae is not parallel to the plane of the under margin of the body of the mandible. These lines converge to the left. This deformity is characteristic of torticollis, a condition in which the sternocleidomastoid muscle on one side develops a contracture at birth or shortly afterwards, probably because of injury, though the exact type of injury is still obscure. The fibrosed and contracted muscle does not grow equally with the rest of the body and causes, therefore, a severe tilting of the head on the neck. If uncorrected, it results in asymmetrical growth of the bones of the skull of the type seen in Skeleton no. 7. It is twice as frequent on the left side as on the right side and that would be the side involved in this skeleton.

"The second lesion presented by Skeleton no. 7 is an abnormality of the 5th lumbar vertebra. On the right side, there is a normal transverse process; on the left side, instead of a transverse process, there is a large mass of bone which resembles the lateral mass of a sacral vertebra. It articulates with the sacrum. This vertebra, therefore, is partially sacralized on the left side and articulates with the sacrum. This has caused a curvature of the spine convex to the left. The space between the body of the 5th lumbar vertebra is wider on the left than on the right and the 5th lumbar body itself is slightly higher on the left than on the right. This congenital anomaly is a common cause of low back pain and sciatica. Almost certainly the owner of Skeleton no. 7 was a victim of backache."

These findings indicate among the earlier, prehistoric population only the presence of two congenital anomalies in the form of (a) torticollis and (b) a lesion of the lumbar region productive of sciatic pain. The historic Huron population on the other hand suffered in at least two instances from Struempell-Marie disease and ankylosing spondylitis. Further examination of the Ossossané ossuary material may reveal other pathological conditions not as yet encountered in it. In this connection, Dr. Harris remarked that he found there none of the "widespread evidence of a type of productive arthritis in-

volving chiefly the vertebral column, and marked by formation of osteophytes at the margins of the vertebral bodies and often fusion of several bodies to one another by this process'' which he had seen in his examination of material from another ossuary in the area (Harris, '49). The facts already established by Dr. Harris throw an interesting side light upon the life of the aborigines in Ontario and suggest further investigation into the relationship, if any, between the respective native environments and the incidence of disease within them.

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NOSE SHAPE AND CLIMATE

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In 1923 Thomson and Buxton demonstrated a close association between the shape of the nose, expressed as the nasal index, and external climatic conditions. They reported, as did Davies ('32) on still larger samples, that the nasal index is more highly correlated with mean annual temperature than with the relative humidity of the air. For "predicting" the index they recommended the use of both air temperature and relative humidity in the regression formula, since temperature used alone was apt to produce considerable errors. The correlations led them to regard "temperature as a dominant factor" though "modified by various degrees of humidity." Davies also considered that "temperature exerts a stronger influence than humidity" in view of its higher correlation coefficient.

In their discussion of the functional significance of these relations, Thomson and Buxton made clear that both tempera-

ture and humidity were concerned. They suggested that the modifications of nose shape in different climates may reasonably be related to the need for moistening the inspired air; for this reason the humidity of the air is obviously of physiological significance. They indicated also that variation of nose shape might bear some relation to heat loss from the respiratory tract. They argued, for example, that "in the tropics the loss of lung water from the respiratory tract is undoubtedly of considerable physiological importance. In air containing the highest relative humidity the existence of a free passage of entry is of advantage, in order that sufficient air may be breathed in to absorb water from the respiratory tract."

That moistening of the air is a prime function of the nasal epithelium appears from the work of Proetz ('41) and Negus ('49). Negus gives physiological, pathological and clinical reasons for the importance of this moistening on the vitality and activity of the cilia, which are in fact more susceptible to changes in the consistency of the film in which they work (and therefore to drying out) than they are to quite large degrees of heating and cooling. According to Dawes and Prichard ('53), Perwitschsky's findings ('27) also suggest that warming is a less important function than moistening of the inspired air. Dawes and Prichard point out the means by which the inspired air is moistened and cleansed are closely related. In providing moisture additional to that contained in the inspired air so as to bring the moisture content to about 95% relative humidity at body temperature, the mucous membrane of the nose in dry climates may secrete even up to a liter of water per day (Proetz, '41).

It follows from these considerations that if the shape of the nose bears some relation to the moistening of inspired air, the nasal index should be most closely associated with the physical factor primarily concerned in the exchange of water from nasal epithelium to inspired air. This factor is the absolute humidity and can be expressed either as the vapor pressure of the air or in terms of its moisture content (in grains per lb. of dry air). The loss of water from the respiratory tract induced by evapo-

rative cooling which according to Thomson and Buxton might also influence the shape of the nose, is likewise governed by the vapor pressure of the inspired air. The amount of heat lost by this evaporative channel especially in hot climates, it may be mentioned, is a relatively small proportion of the total heat loss and the effectiveness of the respiratory tract in desert climates would be reduced by the heat gain from breathing air at temperatures above that of the body. In any case, evaporative heat loss from the respiratory tract and moisture addition to the inspired air would both be functions of the vapor pressure gradient between the external air and the virtually saturated surfaces of the tract. The vapor pressure of the latter may be assumed to remain relatively constant so that nose shape can be directly related to external vapor pressure.

The use of the two separate climatic variates, air temperature and relative humidity, though useful enough for indicating the type of climate associated with variation in nasal index, is thus not entirely adequate to express these postulated functions of water exchange by the nose. To combine them statistically does not furnish the correct physical specification of the outside air.

The data provided by Thomson and Buxton for some 150 living population samples have been re-examined in a preliminary way and the indications are that correlations with the external absolute humidity are likely to be as good as, and probably better than, those with air temperature and humidity. It has not yet been possible to assemble the rather formidable amount of meteorological data (and many of these are probably not available) necessary to obtain the true mean absolute humidity for these 150 locations, but as an approximation the absolute humidity has been derived from the mean annual temperature and mean annual relative humidity as given in Thomson and Buxton's paper. This approximation involves only a relatively small error for polar regions and is unimportant for hot regions (Sumner and Tunnel, '49). Table 1 shows that the original coefficients are appreciably lower than that with the wet bulb temperature or even more so than that with vapor

pressure of the air. From the latter the relation between the nasal index and the amount of water to be secreted, say in 24 hours, to humidify the inspired air could be calculated, if desired.

TABLE 1

NASAL INDEX (146 GROUPS LIVING) CORRELATED WITH	COEFFICIENT	STANDARD ERROR
Dry bulb temperature ¹	0.63	0.050
Relative humidity ¹	0.42	0.068
Dry bulb temperature and relative humidity ¹	0.72	0.040
Wet bulb temperature	0.77	0.034
Vapor pressure of the air	0.82	0.027

¹ Thomson and Buxton ('23).

It would be worth extending the analysis on these lines to many more groups using more detailed meteorological data. The figures given should be regarded meanwhile as indicative of the functional basis underlying the nasal index-climate relationship, namely, the loss of water to the inspired air.

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REVIEWS

THE FACTS OF LIFE. By C. D. Darlington. 467 pp. Allen & Unwin, London. 1953.

A book by Darlington is always interesting and always controversial. The one under review is also important, and it may become influential should the wrong people get hold of it and become able to use its contents. It must be set in its proper historical perspective for its full significance to be appreciated. The current year is the centenary of Gobineau's "Essay on the Inequality of Human Races," which attempted for the first time to give a scientific basis to race and class prejudice. Soon after Gobineau, Galton started the study of human heredity and founded the eugenical movement. Galton narrowly missed true greatness as a scientist, since he proved unable to rise above the preconceptions of his class and of his time. His views of man were essentially those of Gobineau, brought up-to-date in terms of the Darwinian theory of evolution. Scientific eugenics is still trying to overcome fully the Gobineau incubus. After Galton, the current of biological racism widens but becomes shallow. As is generally known, biological racism proved a big popular success, since it gave a scientific sanction to what many powerful people were doing anyway. In Britain and elsewhere it became the white man's biological burden to govern the non-whites, and incidentally the "inferior" whites also. In Germany the current led from Houston Chamberlain's "Foundations of the Nineteenth Century" to Gunther's superiority of the German race, Clauss's "Race and Soul," and other twaddle of the Nazi biologists and anthropologists. In America, the greatest popularity of race theories was reached in the decades preceding and following the passage of the immigration laws. But despite its popularity, biological racism never outgrew its nineteenth century biological underpinnings. It never really mastered Mendelism, and population genetics, and modern theories of evolution remained wholly outside its reach. The importance of "The Facts of Life" is that here an attempt is being made by a first rate modern biologist to state the racist argument not in terms of the biology of 1900 or earlier, but in those of our own day. Not only is the argument thoroughly modern and consequently largely original; it is developed with the aid of fine erudition and brilliant and forceful writing.

The purpose of the book is clearly stated in the preface. It is "to show the immense possibilities which await the application of the elementary principles of heredity (or, as we call it, genetics) to the great problems of society — of education, of medicine, of crime and punishment, of marriage and divorce, of the relations of races and classes, and, taking a long view, of evolution." The author thinks, and this reviewer concurs, that social scientists have not given sufficient consideration to biology in handling these problems. But he chooses a pedagogic method of dubious efficacy to induce social scientists to give more attention to biology. This method is to denounce the social scientists as incompetent not only in biology (which many of them would admit) but also in their own fields (which most of them will resent). Marx, Freud and Toynbee are his aversions; their work is ready for the dust bin, and the thing for social scientists to do is "to go back to Malthus, Darwin, Mendel and Galton, and to make use of the new genetics in interpreting the results." He should have added also Gobineau (whose name is strangely not mentioned in the book), and cut out Darwin and Mendel, since Darwin was notably modest in applying his biological discoveries to social problems and Mendel, as far as known, never tried to apply them.

According to Darlington, "The valid principles [of social science] are those of genetic determination." And "The structure of a society rests on the stuff in the chromosomes and on the changes it undergoes." The genetic determination is very rigid indeed, the environment being mostly powerless to modify its results in any important respects: "Individual adaptability is indeed one of the great illusions of common-sense observation. It is an illusion responsible for some of the chief errors of political and economic administration today." In reality, "The difference that distinguishes social classes is genetic: it is based on genetic materials which are as effective in the cell as economic materials are in the market." This applies, of course, to the "imperial races and governing classes," which "derive their dominant position from the fitness of their genetic character to the conditions they find or make for themselves." Even the occupations are genetic: "Individuals and populations cannot be shifted from one place or occupation to another after an appropriate period of training to fit the convenience of some master planner, any more than hill farmers can be turned into deep-sea fishermen or habitual criminals can be turned into good citizens." At this point many a reader will wonder how did it happen that the industrial revolution has radically changed the occupations of many millions of people within very few generations, and how many no less radical changes in the way of life of people took place in the course of history. In modern societies the son as often

as not adopts a profession different from that of his father; what happens then to the genetic determination?

If genes determine the occupation which the individual chooses, culture must also be genetic: "it [environment] could never determine the development of culture without regard to the human race available. Not only the development but the absorption and exploitation of culture is entirely different among different races and is genetically limited." Some races are superior and others inferior, although not "unconditionally" so. Thus, the Australian black fellows on an island in the Gulf of Carpentaria "are inferior in some important respects such as their capacity for assimilating, exploiting, or advancing European culture," and this is due "to their inadequate heredity."

Concerning these matters of racial superiorities and inferiorities, Darlington is certainly far from the crudities of some racists, although on these matters he does not make his views very explicit. According to him, "It is absurd to pretend that water and vinegar are equal. Water is better for some purposes, vinegar for others. Vinegar is harder to get but easier to do without. So it is with people." This parable is not explained any further, and the reader must decide for himself who are the water and who the vinegar. Repeatedly we are told that the genetically different classes and races should "co-operate" with each other, and that such cooperation is the prime mover of progress. But the example chosen to illustrate the cooperation is the coexistence of whites and Negroes in the southern United States, which does not seem to be a particularly happy goal to strive for. Even so, some people do not seem to be worth cooperating with: "In England, for example, it is not lack of research which limits food production but the genetic unfitness of a large part of the tenant farmers, the legally secured occupiers who are organized to keep better men off the land." What is there to be done with this "large part of the tenant farmers"? For a native of the Gulf of Carpentaria "If, as seems to be the case, education can do very little with him as an individual, then continued education of his race, generation after generation, will do no more." Will the tenant farmer be any more educable?

The conclusions, opinions, and contentions reviewed above have, of course, been arrived at and expressed also by authors other than Darlington, although rarely with equal vigor. What makes Darlington's book unique and important is the derivation of these conclusions. The gist of the argument is summarized effectively in the following lines: "The genetic sequence of civilization . . . is that the genetically fixed capacities of individual men influence their beliefs and their social behavior; secondly, having done so, they in turn influence the

groups in which the individuals will mate; and thirdly, the mating group selects and concentrates the genetic capacities of individual men. By this circular sequence we can now see that a differentiation of society is established on a genetic basis, of which the people concerned are unconscious." Here we do have a cogent theory which must be seriously considered before its truth or falsity is established. Races and classes are mating groups, Mendelian populations. By a process of social selection they absorb the carriers of certain genes from adjacent populations, and by natural selection increase the incidence of these genes. The racists usually regarded their "racial stocks" as the relics of some "pure races" of the past, about to be swamped by the modern panmixia. Darlington's mating groups are dynamic, they continuously form and break up according to the opportunities that arise, and their formation and decay are the skein of which the world history is made.

It is impossible in a review to give an adequate analysis of this theory. This reviewer does believe that, despite its undeniable ingenuity, it is demonstrably false. In the first place, it is not true that what men are and what they do in their lives is largely pre-determined by heredity. The author's favorite whipping-boy, the "social scientist," has produced pretty good evidence (which the author does not deign to mention) that human personality is powerfully influenced by circumstances of his life and education, and that the development of culture is a complex process in which the influence of the environment is far more evident than that of heredity. What is more, the geneticist has uncovered facts which on the whole tend to emphasize the importance of the genetically conditioned plasticity of the developmental pattern of a normal (i.e., free of gross pathology) human. It is regrettable that when the author reviews the biological evidence in his book he hand-picks the examples which suit him best and ignores the rest. Thus, his discussion of criminality in twins is confined to a detailed presentation of Lange's data. Even so, the importance of the environment in human life is too evident to be gainsaid. The author consequently resorts to a most ingenious argument. Man is not a slave of his environment; he chooses an environment which suits him best, and, indeed, modifies and creates environments to fit his tastes. Now, which environment is chosen or created is determined by the genetic endowment of him who chooses. Hence, influences of the environment are merely disguised effects of a person's heredity! Many a reader will wonder how his genotype managed to prevent him from choosing an environment of affluence and security which some people enjoy.

The most serious omission in the book is its failure to make clear that the modern concept of genetic determination emphasizes not

fixed "traits" of the adult organism but the dynamic responses of the developing body to external and internal influences. The genotypes which are perpetuated by natural selection in evolution are those which react most favorably for the survival and reproduction of their carriers in the greatest variety of circumstances to which the race is exposed. From this it follows directly that in variable environments the genotypes yielding a wide adaptive plasticity of responses will be most favored. It becomes evident that in all human societies known to science (and here we have to take the findings of the "social scientist" seriously!) a rigid genetic fixation of cultural capacities, as envisaged by Darlington, would be adaptively disadvantageous and would be counteracted by natural selection. To what extent the mating groups which constitute social classes and races act as foci of concentration of genetic abilities and disabilities we do not yet know with assurance. This will depend not only upon the frequency of intermarriage between the groups but also upon the degree of fixity of the social structure in time. One thing which is crystal clear is that the ability to profit by experience and to be trained to perform different functions as need arises is adaptively valuable in any human society. "The genetic sequence of civilization" is quite different from that imagined by Darlington. The social scientist should not "go back" to the Malthus, Gobineau, Galton, and Darlington. He should go forward, with the aid and cooperation of modern geneticists and evolutionists.

In this reviewer's opinion, Darlington's modern version of biological racism stands critical examination no better than its predecessors. But it should be emphasized that the book under review does present a biological philosophy of history based upon an original, and very ingenious, interpretation of the modern biological knowledge.

The most important thing to realize about this book is that its title is in part a misnomer: the book does contain many biological facts, admirably explained; but it contains also many prejudices of the author. No distinction is drawn between facts and interpretations; hence, the book can be read profitably only by those who can take its contents with several grains of salt.

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RUDOLF VIRCHOW: DOCTOR, STATESMAN, ANTHROPOLOGIST. By Erwin H. Ackerknecht. ix + 304 pp.; 3 illu. University of Wisconsin Press, Madison, Wis. 1953.

When the 19th century was still Occidental culture's latest experience, had there ever been one uglier, yet more violently and

massively fertile, one more swarming with change? It had long been committed to transmission of its learned tradition via a polyglot medium — largely, varieties of Indo-European. It was religiously schismatic, even schizoid. It mobilized a cultural summation peculiar to itself, called nationalism, in furtherance of its power-institution called the State, in such a way as to be self-cannibalistic, and toward other cultures an unabashed pirate. It abolished slavery while sprouting new crops of slums. It evolved mass armies, ballot boxes, machines, and scientists. It built not cathedrals but Crystal Palaces; and turned artists into protesters against society. It destroyed phlogiston and "vitalism," and synthesized urea and constructed the periodic table. It discovered the living cell, the atom, the electron; organic evolution and man's place in nature. It transferred power from kings to capitalists; taught even beggars to read; erected monuments to John Doe In Uniform; exchanged new culture-heroes for old. It bent the time-dimension to its use: on the one hand it immobilized human time-moments on photosensitive plates; on the other, it induced a new time-motion by rendering one side of the world instantly reactive to events on the other side, via electronic transmissions.

It was a Promethean age, while the older gods lived on a spell. Queen Victoria and Rudolf Virchow were born and died within a couple of years of each other. Virchow was indeed Promethean; Victoria indeed was not.

But this is a review of a study of Virchow. The comparison is apt nevertheless — Doctor Ackerknecht similarly lends perspective to his account; that is, by cross-reference. And no one, I believe, could have presented to us more fittingly the life and work of this remarkable physician, statesman, anthropologist than the Professor of the History of Medicine at the University of Wisconsin — himself a physician, anthropologist, and scholar with a historian's perspective. He has handled his Titan skillfully, using a warp-and-weft technique: first comes a biography proper, hardly adorned and austere (the style, for that matter, is austere throughout), of 40 pages; then, more than 100 pages on the work of the physician; over 30 pages on the statesman; about 140 pages on the anthropologist; finally, a brief "epicrisis."

When Virchow was born, such changes as those picked out above had barely begun; he died in a very different world from the one he was born in, and he had wrought mightily, within his chosen fields, to change it. Thus to span, in one's maturity, a great Before and After is a strenuous gift that the fortunes of history have bestowed upon but relatively few of the human race, and seemingly only in recent times. Those of us who have been thus favored are by so much a new kind of human phenomenon. Virchow was a mature man both

before and after Darwin's *Origin of Species*; he was born in a culture still essentially one of trading-cities with crafts, and farming; he died in one committed to the industry of manufacture. Doctor Ackerknecht has had, I believe, to wrestle with his figure: Virchow's life was such a concentrate of achievement that the easiest path for the biographer would have been the descent into unrelieved eulogy; which the author has not done. Virchow earned — the verb is correct — the hatred or distaste of certain physicians, politicians, anthropologists; he furnished plenty of materials for diatribes. Yet much of what he so earned was a compliment to him rather than the reverse. Doctor Ackerknecht is at pains to maintain a balance. He would not neglect to "paint the wart on his subject's nose."

Young Virchow's Germany was romantic, reactionary, relatively backward in medicine and scientific matters, stumbling through frustration toward a political self-realization such as some other nations had achieved in an earlier and simpler age. Virchow was a constructive rebel.

Early 19th century medicine had behind it an honorable tradition as an art not devoid of science. Drugs it had, and the microscope, and surgical instruments of considerable delicacy. Yet it obviously could not be in advance of an as yet non-existent set of scientific discoveries, nor of a scientific philosophy derived therefrom. Organic chemistry comes with the 19th century; the microscope becomes a really focal instrument only then; and anesthesia and antisepsis are innovations. Virchow's contributions either to these or because of these are numerous and versatile enough to daunt any biographer; yet Doctor Ackerknecht seems not to have missed a thing of consequence, and to have guided his material with a firm hand. His subject was a thoroughgoing empiricist, else he could not have made a science out of tissue pathology; applied the cell-theory of living matter to account for neoplasms; and forced the microorganismic theory of disease to the critical self-examination that eventually was to vindicate it. Virchow was both innovator and devil's advocate — in either case, polemically.

The social scientist cannot but be interested in Virchow's social perspective, in medicine first, and by extension later on, in anthropology. He got himself into deep and repeated trouble by demonstrating that epidemics were results of social abominations which government properly could and should eliminate. The bureaucrats did not like it; but Virchow had shrewdly found himself aligned with the *Zeitgeist*. The doctor who was able to slice into government failures in social vision and responsibility and eventually to tilt against Bismarck, had been the young man who fought behind the barricades in 1848. That road led into the Reichstag and psychic

barriades, in their turn, against him. We cannot say the years were wasted, though his objectives and his opposition failed: the Hohenzollerns and the Junkers were already headed for 1914. Doctor Ackerknecht identifies the reasons for Virchow's failures here (p. 189).

By 1860, the doctor's great deeds were practically over; after that, aggregate man invited the anthropologist. We know him as the instigator and director of that great demographic survey of German schoolchildren which substituted racial facts for romantic fictions anent the provenience of the German people. I think it is not uncommonly believed that Virchow opposed Darwinism and refused to allow to Neanderthal man any more status than that of a pathological grotesque. On the contrary, as the author points out carefully, Virchow was very sympathetic toward evolutionary theory; but stickler that he was for facts and more facts, he insisted that favorable entertainment was not the same as uncritical protagonism: he was not an Ernst Haeckel. And fossil finds, during Virchow's life, were indeed rare. He was appropriately intrigued by the discovery of Java man, a few years before he died; but it should have come much earlier in his life. It is true that Virchow advanced the case of human evolution not a whit, and his prestige carried not just a cautionary but a negative weight that here was misplaced. (He succeeded in persuading the discoverer of Java man that it was but a giant gibbon!)

Well-known also is his friendship and support of Schliemann, who uncovered Homeric Troy. Virchow's interest expanded to include the antiquities of the Germans and the neighboring Slavs. He was aware that his own, remote ethnic origins lay back among the latter; in themselves a deterrant to any ethnocentric chauvinism toward things Germanic.

He was one of the founders of German anthropology, while his correspondence was international. Yet his enduring accomplishments lie in medicine rather than in anthropology. As Doctor Ackerknecht says—it was the maturity of medicine as a body, and the inchoate character of anthropology, that favored him in the one and handicapped him in the other.

The imperiousness of convention requires that a review register something adverse against an author's effort, lest praise be unrelieved. The layman will find the extensive lapse into medical jargon somewhat hard to take. In extenuation, let me assure him the cold comfort that it might have been much worse, and I hope he can "take it." The style is lucid though hardly a model of literary excellence. The speleological reader who enjoys the labyrinths of character-study rather than what a man at last leaves behind him, may as well be warned away. But it is the latter interest, not the former, which

Doctor Ackerknecht has been pursuing. And we are very much beholden to him.

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MAN'S ANCESTRY. By W. C. Osman Hill. William Heinemann, Medical Books Ltd., London. 1954. 194 pp. 21/-sh.

The book gives a short account of human phylogeny, stressing, of course, the primate stage about which we know more than about the preceding stages in any event. It starts out with a short consideration of the evidence for evolution, then goes over to the evolutionary horizons of human phylogeny and the evolutionary advance within the chordate phylum. Chapter IV is entitled "How animals find their way about." Then follows the emergence of the primates, the rise of the anthropoids, fossil men, and the stage from palaeolithic to the present. A short chapter on some general problems, such as the exact place at which man branched off and the reasons for the growth of the body leads to the close.

This survey does not do justice to the content, but should help to circumscribe the scope of the book. The text is well written without being scintillating or overly brilliant. Why figure 14 has to be repeated as figure 26 is not quite clear. It is a drawing of *Volvox globator*, hardly important enough in a book on physical anthropology to be brought twice in fairly rapid succession. The book is up to date. In suitable appendices the question of the Piltdown skull and the evidence from South Africa are discussed and evaluated.

Being a neurologist, the reviewer was primarily interested in what the author had to say about the growth of the brain. Let it be said at the outset that the author has something to say about the brain and its growth, in contrast to many older accounts which limit themselves too exclusively to a discussion of the skeletal parts. But the details are in places misleading. In the short chapter on how animals find their way about, there is a diagram of a reflex arc which in the form given is wrong. It involves but two neurons. Such arcs exist, but they go from a muscle spindle to the muscle, never from the skin as given in the diagram. Moreover, when it is said that the two neuron reflex arc is the primitive condition, and the intercalation of further neurons is the higher development, this, too, is to be taken with a grain of salt. We actually know very little about the question, but what we know would suggest that the two neuron reflex arc is a high stage of development, and that the mass reflexes brought about by a greater number of intercalated neurons is the original condition. This at least holds true for the spinal cord. A different kind of prin-

ciple seems to govern the growth of the neopallium, but we do not understand that as well as one might wish. That here again the repression of mass reflexes comes first seems fairly clear. In the footnote on p. 72 we find that "the histology of the motor area is typically primate." In what way does the motor area of primates differ from that of non-primates? Is this a misprint for visual area? What is (p. 78) the evidence that the mangabey is able to distinguish color better than man? And a little further down, it is said that the representation of the sense of hearing is quite extensive and intimately coupled with other sensory areas of the brain. Accounts generally stress how small the area of hearing is. (In the human brain it is actually only a few square centimeters large.) That macaques can unravel knots seems most unlikely, even to chimpanzees a knotted cord is incomprehensible. That the increase in bulk of the brain is larger than can be accounted for by size is not true. That evidence suggests the appearance of right-handedness in the Ehringsdorf cranium, is far fetched, to put it mildly. Some omissions are also of interest: there is no reference in the index to speech or language, and the problems connected with it are not even touched upon.

But no first attempt is successful in every detail. It remains to the credit of the author to have given at least some neurology, and that is worth a lot. If he had read Coghill, Herrick, and LeGros Clark, and perhaps something by Lloyd, that might have helped him considerably.

One question finally: Who is Yvagge Hill who made so many of the drawings which appear in the book but who is nowhere given thanks for it?

The book is a good clear account of the phylogeny of man, and can be read with advantage not only by the intelligent layman, but by the professional student as well.

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THE SCIENCE OF MAN. By Titiev, Mischa. pp. 1-467. Henry Holt & Company, New York. 1954.

The author of this introductory text sets forth to demonstrate "that all phases of man's biological and cultural behavior form an integrated theme that legitimately makes up a single discipline." The result is a well written and orderly presentation of the subject matter and methods of anthropology, without special pleading for any one school of thought. In the belief that biological considerations are prior to and underlie all forms of biocultural behavior the first one third of the book is devoted primarily to physical anthropology. This

first part, "Man in the World of Biology," is composed of 8 chapters. These range from the first forms of life to the biological foundations of culture, with separate chapters devoted to them and to the primates, man-apes and man, extinct hominids, the living varieties of man, and the "new look" in physical anthropology. Each chapter is well illustrated and includes a summary as well as a carefully selected bibliography.

The first two of these chapters are concerned with getting our ancestors out of the water and onto dry land. Here, as in succeeding chapters, the author intentionally touches lightly on many topics which the individual teacher using this introductory text may wish to enlarge upon. Nevertheless, the major topics are there. Whether or not the platypus represents a transitional stage or a comparatively recent development, and the specific nature of generalized versus specialized characters in morphological structure are topics that some may choose to enlarge upon.

References to the major fossil finds of monkeys and apes are included in the discussion of the primate order. The anatomical specialties, such as the rotating forearm, are illustrated by drawing and photograph. In dealing with the South African man-apes and with fossil man the author carefully draws attention to alternative explanations of the significance of particular fossil remains. The skeletal alterations attendant upon erect posture are noted in good detail. Weidenreich's classification has been followed in describing the extinct hominids. Though the date of discovery has not been used in ordering the presentation, the inclusion of historical notes here, and throughout these chapters, provides a helpful guide to understanding the development of anthropological thought. Reference to recent findings on Piltdown Man bring this discussion of human ancestors up to date.

Chapter Seven, "The Living Varieties of Man," gives in straightforward fashion the techniques and results of race classification. The photographs are good, including the traditional white man with arms outstretched over the heads of two amiable pygmies. The reader is carefully warned of the great extent of individual variation within races. Fallacies of racism are discussed. The author correctly states that no race can be considered more highly evolved than another and cites the standard example of comparisons of the three major stocks with a generalized apelike condition, by means of which it is shown that they are similar or dissimilar depending on the characters used. This may be a useful exercise for introductory students, though it serves to keep alive the idea of the validity of these "progress reports" when in fact they are obtuse or inaccurate on several grounds so far as genetic relatedness is concerned.

The use of human blood groups in classification is referred to in chapter eight, "The New Look in Physical Anthropology." The author performs a useful service in pointing out that use of blood group evidence is supplementary to the earlier systems of classification. Some persons may wish to expand the discussion of blood groups and show the places in which they have contributed to sharper or more sensitive classifications and also to an understanding of the genetic process of race formation. The limitations of classification, greater use of genetic principles, selection of measurements appropriate to the problem at hand, better use of statistics, resort to experimental testing and sounder formulation of theory are among the points discussed in this characterization of contemporary physical anthropology. The section entitled, "The Phenotype Makes a Comeback," will be found to be most useful and one that is long overdue. The concept of population, the meeting ground for the use of phenotype, genotype and ecological relations, is emphasized and attention is called to the fact that the forces promoting changes in isolated populations are the same as those which have produced evolution. Studies in human constitution, forensic anthropology, growth, changes in the bodily form of migrants, applied physical anthropology and other important topics are to be found in this chapter or the one preceding.

A discussion of the implications of tool-making, the development of symbolic behavior and cultural versus biological values, contained in chapter nine, concludes this treatment of human biology.

The author has provided an excellent framework upon which particular teachers may enlarge, or from which they may diverge and still have a point of reference within the text. Titiev states that most of the biological material has been included "with a view to clarifying the steps by which man came to have a distinctive body, one capable of devising and continuing culture." This treatment is one with which physical anthropologists will find they can live very comfortably and use to good advantage in introductory courses. It establishes a new trend in providing more cogently and skillfully organized data and inferences from physical anthropology which are essential to a sound appreciation of human biocultural achievements.

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CLINICAL GENETICS. Edited by Arnold Sorsby. Butterworth and Co. (Publishers), Ltd., London, England. The C. V. Mosby Company, St. Louis, Missouri. 1953. Price \$17.50.

Clinical Genetics is the first major *critical* survey work on human, or more accurately, medical, genetics to appear in English. Arnold

Sorsby, the editor, has elected to develop the subject of medical genetics along two lines, theoretical and clinical. On the whole he has been eminently successful. The task, however, of editing and compiling a compendium such as this is not without risk particularly with regard to evenness and balance in presentation. Herein lie the major deficiencies in the present work.

It is clearly stated in the preface that this is not a textbook of human genetics, and that it is assumed that the reader will have some familiarity with basic genetics. This would account for some unevenness in presentation. The reviewer assumed, however, that this book is directed not only toward the professional human geneticist but also to the informed physician or layman who desires some knowledge of the types and kinds of problems which arise in medical genetics, and some idea as to current thinking in this field. The latter individuals can only be misled when they see more space devoted to human cytogenetics than to the biometric evaluation of data, and as much space to the evaluation of linkage as to clinical varieties of inherited disease. They will be no less misled as to the criticalness of current thought when they see a 115-year-old pedigree, largely of hearsay evidence, explained in terms of attached-X chromosomes, a phenomenon which has not been cytologically demonstrated in man, when the more obvious inadequacies of the pedigree are overlooked. In this review, since space is at a premium, we shall concern ourselves primarily with the theoretical considerations, an area where, presumably, the clinician would be least qualified to adequately appraise the statements and evidence presented.

Under "Theoretical Considerations" appear 10 chapters variously entitled "Clinical Varieties of Genetic Disease," "Penetrance and Expression," "Detection of Genetic Carriers of Inherited Disease," "Twin Studies," "Sex Limitation," "Polygenic Inheritance," "Evaluation of Linkage," "Mutation," "Biometric Evaluation of Findings," and "Experimental Methods (Cytogenetics, Chemical Genetics, and Comparative Pathology)." The list of authors is no less impressive than this subject list, and in the main, their contributions are adequate if not always stimulating. Two exceptions to this generalization are Koller's and Dahlberg's chapters. We shall return to these chapters in a moment, but first let us consider some minor objections to the other chapters in this section.

Waterhouse (Chap. IV, p. 39) calls attention to the variation in DZ twinning with maternal age, and the observation that the rate of DZ twins is appreciably lower than the rate of MZ twins among offspring born to mothers under 20 years of age. He suggests then that "the low rate of DZ twinning found in some Eastern countries (Japan, for example) may be explicable on the basis of a relationship sensibly the same as that depicted in Figure 6 (maternal age

effect), taken in conjunction with the early age of marriage customary in such countries." For the past 5 years the reviewer has been associated with the atomic bomb follow-up studies on the populations of Hiroshima and Nagasaki. One outgrowth of these studies has been the examination of the products of some 85,000 pregnancy terminations. Two facts of interest here emerge from these examinations: (1) the twin rates in Hiroshima and Nagasaki are sensibly the same as those Komai and Fukuoka have reported for other regions of Japan, and (2) the mean maternal age at birth of the first child is 24.127 ± 0.042 years, a figure not markedly different from that characteristic of the U. S. A. Moreover, less than 1.5% of the births in Hiroshima and Nagasaki occur to mothers of less than 20 years of age. These observations suggest that Waterhouse's thesis, though interesting, is not valid. In the same section (p. 44), it is flatly stated that the most effective test of zygosity is a skin graft. The reviewer is aware of no large body of human data which would support this assertion. Moreover, since skin grafts are successful in fraternal twin cattle when they are erythrocyte mosaics, plus the fact that such mosaics are known to occur in man, the skin graft test does not seem a sufficient condition in determining zygosity.

As a clinical illustration of a simply inherited sex limited trait, Ford (Chap. V, p. 48) cites Snyder and Yingling's data on pattern baldness. This is an unhappy choice since it can be readily shown that Snyder and Yingling's data do not agree with an hypothesis of a pair of alleles one of which is dominant in one sex, but recessive in the other. Under such an hypothesis, the maximum likelihood estimate of the gene, say p , is the real, positive root of the cubic equation

$$p^3 - p^2 \left[1 + \frac{N_f}{N} \right] - p \left[\frac{B + 2b\delta}{N} \right] + \left[\frac{2B\phi + B\delta}{N} \right] = 0$$

where N is the total number of observations, N_f the total number of females observed, B the number of bald individuals observed among all individuals, $b\delta$ the number of non-bald males, $B\phi$ the number of bald females, and $B\delta$ the number of bald males. The invariance of this estimate is

$$I = 4 \left[\frac{N_f}{1-p^2} + \frac{N_m}{1-q^2} \right].$$

From Snyder and Yingling's data, one obtains as the M.L. estimate of p , 0.255195. When this estimate is fitted to the observed distribution of baldness one obtains a $X^2 = 6.816$ which for one degree of freedom is clearly significant. In short, these data are not consistent with the hypothesis they purport to demonstrate.

Mather's statement (Chap. VI) of the problems of quantitative inheritance is a realistic one although developed in terms of polygenes which some individuals may find objectionable. However, it is unfortunate that Wright's very excellent 1952 paper (The Genetics of Quantitative Variability) does not appear in the bibliography. A small error exists on page 59, r_p / o and r_s / s have their maximum values at one-half and not at one as stated. This is obviously an oversight.

MacGregor's treatment of the problem of linkage is somewhat startling because of the complete omission of reference to the work of Fisher, Finney, and Bailey on the detection of linkage. The treatment is somewhat sketchy, and MacGregor certainly does not carry the problem further than half a dozen introductory texts do. This, however, is probably adequate for the clinician.

The chapter on mutation is well handled, and Crew manages to dissociate himself from either of the extremist points of view with regard to the frequency of the phenomenon. It does seem, however, that somewhat more attention could have been paid to the problem of estimation of mutation rates in man. Catheside's treatment of chemical genetics is possibly overly succinct, but certainly well done. It provides an adequate, knowledgeable background for Klein's chapter on the metabolic disorders.

Dahlberg's chapter on the biometric evaluation of findings is inadequate largely for what it leaves unsaid. This is the subject matter for a much needed book in human heredity, and in the reviewer's opinion, unless the editor was willing to devote at least 100 pages of text, this topic would best have been left untreated. The problems of gene frequency estimation, age corrections, and a host of other items are not even mentioned, and ascertainment is developed and treated in a markedly pedestrian fashion omitting all reference to the maximum likelihood approach. The Weinberg and Dahlberg methods, which are given, are rarely used in England or in the U. S. A. largely because of their inefficiency. Dahlberg's was indeed a thankless task.

The most serious lapses of criticalness in the entire book are to be found in Koller's chapter on cytogenetics. Koller seems compelled to explain, in genetic terms, a number of unusual pedigrees, and to this end he trots out position effect, attached-X chromosomes, trisomy, and deletion. For only one of these, deletion, does there exist even the vaguest sort of cytological evidence that the phenomenon is occurring in man. The choice of these sophisticated hypotheses seems naive indeed when one notes that the pedigrees can be much more readily explained in terms of misdiagnoses, hearsay evidence, or inadequate techniques. More questionable is his discussion of partial sex-linkage. The latter is treated as an established fact despite such work as Sachs, and others (see Matthey).

The real contribution of this book to medical genetics lies in its appraisal of the clinical evidence. Here are discussed some 19 subjects including inheritance of morphological and physiological traits, metabolic disorders, each of the major organ systems, oligophrenia, psychiatry, endocrine disorders, infectious diseases, allergy, and cancer. It is difficult and unfair to single out specific chapters for commendation since the topics impose burdens of unequal complexity on the authors. However, at the risk of being unfair, Falls' chapter deserves mention because of the enormity of the task it imposed. The literature on skeletal abnormalities is legion, and unlike the skin, eye, and others, there exists no other major genetic summary of this system. While there are minor lapses in a number of the clinical chapters, e.g. the absence of reference to the work of von Knorre, and Melevi and Rosler on cardiac anomalies, the one section which does not meet the standard established by the others is the one on hemorrhagic diatheses. This is a rapidly expanding field, and considerably more is known about coagulation defects than Jackson would lead the reader to believe.

One of the more or less standard features of the clinical section which pleases this reviewer is the summary of the present status of our thinking, either in terms of mode of inheritance or empiric risk of occurrence or recurrence, which follows the discussion of the majority of the inherited diseases. These summaries will be of immense value to those geneticists and physicians called upon to do genetic counseling.

Clinical Genetics, while it does not rise to the stature of the *Handbuch der Erbbiologie des Menschen* as a reference work, deserves and will undoubtedly earn a prominent position in the library of every human geneticist.

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DYNAMICS OF GROWTH PROCESSES. Edited by Edgar J. Boell. vii + 304 pp., Illus. Princeton University Press, Princeton, New Jersey. 1954. \$7.50.

"Dynamics of Growth Processes," edited by E. J. Boell is the outcome of the Eleventh Growth Symposium, held in 1952. The 13 papers in this generally well printed and not too expensive volume range from virus reproduction and protein synthesis, to the different curves of population growth. Of particular interest to physical anthro-

pologists are Gaunt's paper on chemical control of growth in animals, Greulich's contribution on skeletal status, Sholl's essay on growth curves, and Dickerson's summary of hereditary mechanisms in animal growth.

Greulich's 11 page paper is marred by the poor quality of the reproductions. Otherwise it reviews, rather briefly the relationship between skeletal "status" (based on carpal x-rays) and bodily maturity in normal growth, in precocious puberty and in endocrine dysfunctions. Further, Greulich comments on scars or scoring, and suggests a possible explanation for the absence of scoring in the presence of known growth disturbance.

Sholl's very readable and largely non-mathematical paper entitled "Regularities in Growth Curves" is a welcome relief from the pandemic disease of excessive curve-fitting. Of allometric growth he says, "I venture to think that too extensive generalization is one of the dangers of the allometric method" and further reminds us that human data are often equally well described by simple linearity. Sholl adds something new to the analysis of size increments demonstrating (for one case at least) the existence of a regular rhythm in stature gain. Unlike the "seasonal" variations in weight gain, so neatly demolished by Turner, this rhythm need not be attributed to light summer and heavy winter clothing.

Dickerson who is known to most of us from his 1947 paper on hereditary obesity in mice, has summarized data of extraordinary interest in his essay "hereditary mechanisms in animal growth." Selections from the summary, such as the following, best illustrate the obvious applicability of animal findings to man.

"Both selection experiments and studies of genetic correlation have shown that genes influencing rate of growth in body weight have proportionately larger effects on fattening and fleshing than on skeletal growth, and even smaller effects on the appendages."

"Studies of selection and of genetic correlation both have shown that the genes which increase rate of body growth also tend (1) to maintain or improve viability during the growth phase, (2) to increase efficiency in utilization of food for the same gain in weight but not necessarily for growth to the same degree of fatness or to mature size, (3) to cause earlier sexual maturity and larger numbers of ovulations by females in litter bearing animals and (4) to cause superior intra-uterine nutrition of the young, but perhaps slightly inferior lactation."

The papers mentioned, especially the last may well be required reading for graduate students and their instructors as well.

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PHYSIOLOGY AND BIOCHEMISTRY OF THE SKIN. By Stephen Rothman. University of Chicago Press. xiii + 741 pp. 1954. \$19.50.

Physiology and Biochemistry of the Skin by Stephen Rothman (of the University of Chicago) and 6 collaborators is an encyclopaedic, useful and outstanding book, though priced somewhat beyond the reach of the individual budget. In its 741 pages there are 28 chapters, 7 of them written by collaborators, each copiously illustrated and furnished with a most complete list of references. The author index is keyed to the chapter bibliographies as well as to the textual references, thus giving this book the status of a bibliographic work.

It is difficult to single out those chapters of most interest to physical anthropologists, for all of them are intriguing and will divert any reader not strongly steeled against browsing. However, chapters 6 (sweat secretion), 10 (the role of the skin in thermoregulation), 22 (pigmentation) and 26 (hair growth) will prove immeasurably useful in bringing lecture notes up to date. Special mention should be made of chapter 16 (the keratinization process).

Throughout, Doctor Rothman and his associates display a heartening interest in evolution, and in the adaptive nature of specific dermal modifications. They explore the various racial differences in the skin, hair and associated glands. Selected quotations may serve as samples.

"Phylogenetically, the loss of a natural fur coat in man had gone hand in hand with the development of eccrine sweat glands over the entire skin surface and with an efficient nervous and humoral control of the sweat apparatus. *Thereby man has acquired protection against severe heat far superior to that of other animals.*" (p. 603). (The italics are the reviewer's.)

"The pigmentary nature of melanin further serves to offer some protection against harmful excessive solar radiation and constitutes an important component of eye structure for efficient function." (p. 520).

"Differences between white and Negro adults were quite pronounced, Negro men having 70% more hair fat than white men, and Negro women about 60% more than white women." (p. 297).

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HUMAN HEREDITY. By James V. Neel and William J. Schull. University of Chicago Press. 1954. 361 pp. \$6.00.

Although the science of genetics, dating from the rediscovery of Mendel's work at the beginning of this century, is not really a new

science, the full force of its impact upon the biological sciences is only beginning to be appreciated. This is particularly true of the applications to man. Until recently many, if not most, physical anthropologists did their work and published their results in obvious innocence of genetic concepts, and famous surgeons were heard to express skepticism as to the possibility of excluding paternity by blood grouping tests. All this has changed in the last decade. There are few physical anthropologists today who make no use of genetical methods, and there is a rapidly growing movement to make human genetics a part of the curriculum of every medical school in the country. The use of genetic concepts has even extended to paleontology, as seen, for example, in the writings of G. G. Simpson.

One consequence of this late realization of the importance of human genetics is a shortage of qualified experts and suitable text-books. The appearance of the present book is an indication that both of these shortages are being remedied. Doctor Neel is Associate Geneticist at the Institute of Human Biology and Associate Professor in the School of Medicine, University of Michigan. He possesses a Ph.D. degree (earned in genetics under Dr. Curt Stern, another specialist in human genetics), and an M.D. degree. Doctor Schull is Assistant Geneticist in the Institute of Human Biology, and holds a Ph.D. degree. Both have been prominent in the work of the Atomic Bomb Casualty Commission as well as the Heredity Clinic of the University of Michigan, and thus bring a wealth of practical experience as well as broad theoretical knowledge to their task. Considering these facts, it comes as no surprise that their new book constitutes the best introduction to the subject of human genetics which has yet appeared.

The authors present the basic facts of genetics, the specific applications to man, and the necessary background of relevant subjects such as probability theory. Few assumptions are made as to previous acquaintance of the reader with such material. The exposition is made more concrete in many places by the use of illustrative material from the files of the Heredity Clinic at the University of Michigan.

The book is divided into 20 chapters, which treat such subjects as the physical basis of heredity, man's genetic diversity, nature and nurture, recessives and dominants, more complex situations, linkage, mutation, analysis of family data, genetic counseling, and eugenics. There are numerous tables and figures and an author index and a subject index.

Although the book is simply written, and will be intelligible even to those who are new to the subject, it possesses one new and notable feature. The requisite mathematics, which is mostly merely algebra,

with a few elementary applications of the calculus, is presented as it is needed, with no attempt at disguise. The authors rightly believe that this necessary for the student who hopes to understand modern genetics in its totality. Nevertheless, it would be possible to read the book with profit without mastering a single equation, and this reviewer would urge all anthropologists, whether trained in mathematics or not, to read it. The presence of the mathematics in no way detracts from the simple and lucid exposition of the material. Instead, it is likely to make the book one to which the practical worker will turn again and again as he perceives the need for an understanding of the mathematical treatment of evolutionary change, gene frequency calculations, estimation of linkage, etc.

The book is not of course written from the point of view of the anthropologist, but this was not to be expected, and would hardly even have been desirable. Anthropological genetics is simply human genetics, and the reader who has mastered this book will be fully able to apply genetic concepts in his thinking. Such applications, of which we may confidently predict there will be many, will constitute, not genetics, but anthropology.

All physical anthropologists will surely wish to have a copy of this unusual book, at once simple and complete, at once provocative and authoritative, so outstanding for the clarity of its exposition of the basic principles and its complete presentation of the methodology, experimental and mathematical, of this important subject.

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